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New trends in integrated science teaching

Volume V

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Preface

This publication is the fifth on the subject of integrated science teaching in the Unesco series 'The teaching of basic sciences'. The first two (*New Trends in Integrated Science Teaching*, Volumes I and II) attempted to analyse world-wide trends in this rapidly-evolving field. The third and fourth addressed themselves to two crucial problems, namely the education of teachers (Volume III) and the evaluation of integrated science education (Volume IV).

The present volume is based on the proceedings of a conference organized in April 1978 at the University of Nijmegen (Netherlands) by the International Council of Associations for Science Education (ICASE) and the Netherlands Association for Science Education (NVON) with support from Unesco and other bodies, including the Committee on the Teaching of Science of the International Council of Scientific Unions (ICSU). The conference's main aims were to take stock of the developments in integrated science education over the last ten years and to provide an opportunity to look forward to new trends in science education in the 1980s and beyond.

Although some countries have been involved in aspects of integrated science education for many years, 1968 marked the first occasion when it was reviewed internationally. This was the conference held in Varna (Bulgaria) at which objectives were assessed, definitions reviewed and projects planned. In 1973, at the University of Maryland (United States of America) there was a major meeting on the education of teachers for integrated science. The Nijmegen conference, coming ten years after the Varna meeting, provided an opportunity for reviewing the scientific and educational reasons for the developments in integrated science education at various levels in the educational systems of different countries. It also attempted to assess successes and failures and to plan new avenues for development.

The conference was intended to stimulate thought and, in particular, to provoke activity at a number of levels, at national and local conferences and workshops, in colleges and in schools. The participants had widely-varying backgrounds and the questions raised at the conference and the tentative solutions offered may not be universally applicable. However, it is hoped that they will be of use in sensitizing all those who are working in this field to the educational possibilities opened up by the introduction of integrated science courses.

The views of all the working groups of the conference, together with extracts from the papers presented, form the text of this volume. There is also an extensive bibliography of relevant books and articles. The topics covered include many aspects of integrated science education itself, including its social relevance, as well as its relation to environmental education, technological studies, and health and nutrition education.

The readership for which this publication is intended is a wide one, including practising teachers and teachers-in-training as well as teacher-educators, science curriculum development and research workers, and Ministry of Education officials. It is suggested that selected portions of the book be used as resource material in science education workshops and conferences organized by professional bodies concerned with science education.

Appreciation is expressed to all those whose participation made the conference a success and, in particular, to all contributors to this volume who generously gave of their time and energy and, in some cases, allowed the use of copyright material. Particular acknowledgement is due to the Editor, Ms. Judith Reay of the University of the West Indies, St. Augustine, Trinidad and Tobago.

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Foreword

This book is an outcome of the International Conference on Integrated Science Education Worldwide held at the University of Nijmegen in the Netherlands from 28 March to 7 April 1978.

Some of the chapters are abstracts of plenary papers given by scientists and science educators of international distinction; these papers helped to stimulate group discussion and private reflection. There has been no space for the full text of the papers, but the addresses of the authors are supplied for readers who would like copies of the original papers.

The other chapters arise from the working groups. The authors, already experts in their own fields, began their task by carefully researching the growing body of literature so that the discussions would go beyond intuition. Then they posed sets of questions to which they needed answers from the groups, so that the chapters appearing here reflect the inputs both of authors and participants. The authors acknowledge the invaluable contribution provided by the collective wisdom and experience of the working groups. Participants brought greater or lesser degrees of experience, but each experience was unique in a way which served to illuminate the discussions, and consequently to illuminate these chapters. The authors also acknowledge the support they received from the working group chairmen and rapporteurs, who guided and recorded the discussions.

The annotated bibliography of integrated science education is supplementary to the bibliography in *New Trends in Integrated Science Teaching Vol. III*, and attempts to sample the great volume of literature relevant to integrated science education. Those who prepared the bibliography have had to rely to a great extent on information sent to them, so that in some cases the data are incomplete although all items are identifiable as they stand.

I should like to express my gratitude for the co-operation and understanding of the authors before, during and after the Conference; to Professor Charles Taylor for his guidance and other help during the Conference as Assistant Editor; to Dennis Chisman, Conference Chairman, at all stages; and to Unesco for its encouragement and advice.

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Abbreviations

AAAS	American Association for the Advancement of Science	LISIP	Lesotho Introductory Science Improvement Programme
AES	Agriculture as Environmental Science	LSS	Lower Secondary Science Project
ALECSO	Arab League Educational, Cultural and Scientific Organization	MATAL	[Elementary Science Teaching Project] (original in Hebrew)
ASE	Association for Science Education	MINNE-MAST	Minnesota Mathematics and Science Teaching Project
ASEP	Australian Science Education Project	MIT	Massachusetts Institute of Technology
ASTEP	Australian Science Teacher Education Project	MTTs	Mobile Teacher Trainers
BBC	British Broadcasting Corporation	NCERT	National Council of Educational Research and Training
BSCS	Biological Sciences Curriculum Study	NSTA	National Science Teachers Association
CBA	Chemical Bond Approach	OAS	Organization of American States
CNS	Contemporary Natural Science	OPEC	Organization of Petroleum Exporting Countries
CRIB	Curriculum Resources Information Bank	PLS	Progress in Learning Science
CROASE	Caribbean Regional Organisation of Associations for Science Education	PPS-CN	Proyecto de Perfeccionamiento en Servicio, ciencias naturales
CSE	Certificate of Secondary Education	PRONA-MEC	Programa Nacional de Mejoramiento de la Enseñanza de las Ciencias
CXC	Caribbean Examinations Council	PSI	Project for Science Integration
ECBA	European Communities Biologists Association	PSSC	Physical Science Study Committee
ECCP	Engineering Concepts Curriculum Project	PSST	Primary Science Scheme of the Territory
EDC	Educational Development Center	RECSAM	Regional Centre for Education in Science and Mathematics
EEC	European Economic Community	S-APA	Science - a Process Approach
ESS	Elementary Science Study	SCISP	Schools Council Integrated Science Project
FAO	Food and Agriculture Organization	SCOPE	Scientific Committee on Problems of the Environment (ICSU)
FAST	Foundational Approaches to Science Teaching	SEPA	Science Education Programme for Africa
Funbec	Fundacao Brasileira Para o desenvolvimento do Ensino das Ciências	SISC	Scottish Integrated Science Curriculum
FUSE	Federation for Unified Science Education	SISCON	Science in a Social Context
GCE	General Certificate of Education	SSSL	Samoan Sea Study Lab
IAC	Interdisciplinary Approaches to Chemistry	STA	Science Teachers Association
IBRD	International Bank For Reconstruction and Development	STAN	Science Teachers Association of Nigeria
ICASE	International Council of Associations for Science Education	STEP	Science Teacher Education Project
ICSU	International Council of Scientific Unions	SUM	Science Uses Mathematics
ICSU/CTS	ICSU Committee on the Teaching of Science	TRUAS	Television and Radio Education
IES	Interrelated Explorations in Science	UNDP	United Nations Development Programme
IPN	Institut für die Pädagogik der Naturwissenschaften	UNEP	United Nations Environmental Programme
ISCS	Integrated Science Curriculum Study	Unesco	United Nations Educational, Scientific and Cultural Organization
ISIS	Individualized Science Instructional System	Unicef	United Nations Childrens Fund
ISP	Integrated Science Program	USAID	United States Agency for International Development
ITP	Individualized Teacher Preparation	USMES	Unified Science and Mathematics for Elementary Schools
IUCN	International Council for the Conservation of Nature and of Natural Resources	WAAST	West African Association of Science Teachers
		WHO	World Health Organization
		WISC	West Indies Science Curriculum
		WISCIP	West Indies Science Innovation Project
		WMO	World Meteorological Organization

1. A scientist's view of the Nijmegen Conference

Charles Taylor

Condensed from a plenary address

As an academic physicist, I have always felt that the differences between the disciplines are not implicit; they began to be codified in the late nineteenth century, but really arise as differences of viewpoint between the scientists. In other words, the significant thing is not that chemistry differs from physics, but that the chemist's view of the world differs from that of the physicist. I should like to see teaching in primary schools arranged so that children are not conscious of the differences between science and singing or between singing and story time. They should accept them all as part of life and of living and of our curiosity about the world around us. But we must be realistic; the whole paraphernalia of university departments, of professional bodies, and of learned societies is based on well-defined and separated subjects, and we must be prepared to deal with all the traditions and rigidities of the past. When, as head of a physics department, I am asked 'Would you take into your department a student who has been brought up on integrated science at school?' my answer is usually that I am more interested in the student's quality of thinking than in precisely what he knows; given the motivation, it would not be difficult to compensate for any informational deficiencies.

PEOPLE MATTER

This was a recurring theme and, in the context of the Conference, it should have special reference to children, but not exclusively so. I am reminded of Professor Hooykaas of the University of Amsterdam who almost 20 years ago pointed out that science had been depersonalized for the last 100 years. In the 18th century, he said, pictures in science textbooks showed the experimenter in full academic robes amongst his apparatus in the laboratory. In the late 19th century the experimenter is reduced to a detached pair of hands. But in the first half of the 20th century even the hands disappear and the experiment seems to be performing itself! It is gratifying to have seen in the exhibitions of project material and textbooks that the trend has now been reversed, and people are back in the illustrations.

INTEGRATED SCIENCE LIVES!

The chapters by Haggis and Adey, Gadsden and co-workers, and van der Cingel and Cheong, amongst others, report many projects on integrated science round the world, especially in developing countries. All of these have been developed since the Varna Conference of ten years ago and are proof that integrated science is on a very firm foundation.

INTEGRATE EARLY - BUT THE HIGHER THE FEWER

There is considerable agreement on the value of early integration of science itself and of science with other areas of knowledge. The chapters by Terlouw, Ahmed and Harlen are evidence of this. But one begins to find doubts creeping in as consideration of older age groups begins, as the chapters by Lambert and Fensham show. I suspect that this is not for any intrinsic reason but rather because, as students get nearer to the point of departure from school, teachers and administrators feel the need to conform more closely with tradition. Had the history of 19th century science been different, we might have found ourselves in 1978 at a conference to discuss the desirability of splitting traditional integrated science into separate sciences!

BUT IS IT RESPECTABLE?

A number of chapters, especially Showalter's, give eloquent theoretical justifications, but I have to admit some doubts about their validity. I tend to agree with Rutherford, without accepting the whole of his treatment, that the case on paper is fairly well balanced for and against, and Booth seems to take the same view. What matters to me is the purely pragmatic test. Are the children emerging from integrated science courses livelier, more motivated, more interested in scientific aspects of the world around them? Are the delightful curiosity and uninhibited questioning of the seven-year-olds - which so often seem to have been squeezed out by the age of 13 or 14 - better preserved? If the answer to these questions is 'Yes' then, for me, integrated science is respectable. But I have a sneaking suspicion that, in the end, the curriculum is less important than the quality of the teaching.

SYSTEM SPELLS SUCCESS

One of the messages that has come across quite strongly is that if you are to sell integrated science, you must not only have a well argued case for respectability but also a systematic approach. The papers by Rutherford, van der Cingel and Cheong, and Ferreyra show that you need a complete package of outlines, materials, resources, costings and so forth to show that you mean business.

EVALUATION IS ESSENTIAL

I think we must agree with Rutherford and Bajah that one must attempt to measure success. But as a practising scientist I am bound to say that one can be misled by purely formal procedures. In science, intuition, the jump in the dark, plays a significant part, and the art of being a scientist is to be able to recognize when your results are leading you in the right direction and when they must be treated with caution. When we apply evaluation procedures, let us remember the importance of common sense in interpreting the results.

IS ER EEN DOKTER IN HET HUIS?

This Dutch phrase symbolizes the cry for help in any language from people working, perhaps by themselves, remote from supporting agencies and totally overwhelmed by the volume of words and paper that pour out from conferences, project organizers, publishers, ministries of education and others. The chapters by Ferreyra, by Pitre, and by Selim, Vaernewijck, Frey and Lockard face this kind of problem. On the whole the scientific community is good at responding, though it is sometimes a little insensitive to the needs until attention is firmly drawn to them. Associations for Science Education work remarkably well in giving non-governmental, non-hierarchical help to teachers. The Nijmegen Conference on Integrated Science Education World-Wide (28 March - 7 April 1978), jointly organized as it was by scientific and educational associations, exemplifies the recognition of a common cause. But we must not forget the importance of personal relationships and once again I must stress that people matter.

IT'S TOUGH ON TEACHERS

In discussing the future, Terlouw warns that 'Those who know what the problem is and still teach carry a heavy responsibility'. Teacher education was stressed throughout the Conference; teachers were urged to become involved in development; teachers were urged to persuade their authorities of the need for change in the approach to science. The load being placed on teachers is indeed a heavy one. The courses discussed at the Conference pre-suppose the interest of the teachers, but there are teachers and university staff who are just not interested in doing anything beyond the bare minimum of duty. It does not seem that we have found a way of reaching these.

FASHIONS FLUCTUATE

Integrating themes discussed include the environment, health and nutrition, agricultural and food problems, and others. But we must be ready to take account of changes in fashion and not become too rigidly tied to one theme. At the moment the environment is 'in', but Terlouw warns that already there is danger of thinking of environmental problems in isolation and to the exclusion of other problems, which can lead to agonizing crises. It seems that there is a case for built-in flexibility.

COMMUNITY CONTACT

In spite of fluctuations in fashions, I would venture to predict that one element that is likely to remain for many years to come is contact with the community in some form or other. Terlouw, Ahmed, Dyasi, Hofstein, Raw and Lewis have considered relevance to the home, to the village, to the city, to industry or to world problems. Incidentally, in considering the wider implications of the science and society issue, we ought to attend to the public image of the scientist given in the communications media. Films and plays show the scientist as a criminal lunatic or an eccentric; the nice solid family man is always in advertising or insurance!

WATCH YOUR LANGUAGE!

D'Ambrosio's chapter considers the relationships between subjects, including mathematics, and stresses the importance of language in the development of thought. This is an area where my interest as chairman of the International Council of Scientific Unions (ICSU) Committee on Teaching of Science is particularly strong. In other chapters the question of language as a barrier crops up, and Terlouw referred to the difficulty experienced by physicists in understanding one another's jargon. Some jargon is inevitable - but it can arise from laziness. Commentaries or even translations by someone from another discipline may help to bridge the gaps. My own Union (International Union of Crystallography) plans a pamphlet to help other scientists to understand the jargon and symbols of crystallographic papers sufficiently to be able to gain information that is useful and also to be able to understand its limits of validity.

WHAT DID THE CONFERENCE ACHIEVE?

I believe an important result was the spirit of co-operation, the feeling that people working together in their groups were really beginning to understand one another a little, to find that the problem of one individual was surprisingly similar to that of someone else in a totally different region of the world. There can be no single grand strategy that we could publish and say 'That is what we achieved at Nijmegen'. We did gain the information, the support and the strength to go back to our own spheres and achieve something there where it really matters.

2. The role of science in education

Norman Booth

Footnotes express the views of the Working Group

INTRODUCTION· THE AIMS OF EDUCATION

Ten years after the Varna Congress on the Integration of Science Teaching (11-19 September 1968), it is worth reminding ourselves of its conclusions, of which I quote the first five.

- i. The teaching of integrated science contributes towards general education, emphasizes the fundamental unity of science and leads towards an understanding of the place of science in contemporary society. It avoids unnecessary repetitions and permits the introduction of intermediate disciplines.¹
- ii. A course of integrated science should emphasize the importance of observation for increased understanding of the environment, it should introduce pupils to logical thinking and scientific method.
- iii. As it may be necessary in an integrated course to omit some details it is essential that the content of the course should be judiciously chosen. It must be carefully compiled by collaboration between the different teachers and other specialists.²
- iv. The extent of integration and the balance between integration and co-ordination will depend on the age of the pupils, the type of educational institution and local conditions. At the earlier stages of secondary education a totally integrated course in experimental science appears generally desirable especially for those students who have decided not to specialize in science.³

-
1. The Working Group agreed with this, but not with the implication that it could *only* be achieved through integration, in the sense in which the word is usually used. Whilst it was agreed, for example, that, as one member put it, 'multiple learning experiences around the same concept probably strengthen the ability of the learner to retain and transfer this concept', there were those who were of the opinion that it was largely a matter of breakdown in communication and co-operation which resulted in this happening all too seldom when the separate sciences were taught.
 2. Have we not reached a stage where interests other than those of the subject specialists must have a voice in content choice?
 3. Yes, but for all pupils whether or not they intend to specialize later. Integrated science programmes can be planned for any student, gifted or not.

- v. Science is an important part of primary education, particularly arousing scientific curiosity and in developing scientific attitudes and skills [269, p. 43-4]¹.

We cannot divorce the aims of science education from the aims of education in general, and Nunn has pointed out that the primary aim of the latter is to help children achieve the highest individual development of which they are capable [414]. More specific statements are provided by Unesco's reports of the broad national aims of various countries [455] which illustrate how much there is in common among nations and the lines along which they differ. Another useful statement comes from England and Wales [382].

Coombs, however, points out that education is not a cure for all the ills of the world, with limited time and means, education is an act of faith that it is doing what is best for the individual and his society, and that it is not wasting too much of its resources and time in doing things that are wrong or irrelevant [376, p. 5]. Some nations have an inspectorate whose function is very largely to ensure as far as it can that things go beyond an act of faith.

Coombs makes another point of great relevance to any discussion about proposals to change the direction of science education. Hoping that education will get them a good job in their developing society, students' job preferences are often set in the past, prestige-carrying but not fitting the manpower requirements for economic growth. The incentive structure and the employment demands of the market place may also reflect the old hierarchy of prestige, leading to serious disjunction between the stated developmental goals of society and society's anti-development patterns.²

It is all very well to demand of formal education that it endeavour to persuade more pupils to work in agriculture, as in the Central African Republic, or in engineering, as is currently the case in the United Kingdom, but if the prestige and the material rewards go to the lawyers, the accountants, and the science researchers, then that is where the best brains will aspire to go. Not only that, but in practice, however noble the written aims may be, it is to those ends that the best efforts of the schools and the rest will be directed. With Coombs, I doubt the reality of transforming the 'elitist system' unless by that is meant replacing an out-moded elitist system by one which is more closely related to the needs of the times and of the people who live in those times.³

That then is part, and a major part, of the background against which we have to set our search for realistic and attainable aims and objectives for science education.

PURPOSES OF SCIENCE EDUCATION IN THE PRIMARY SCHOOL

Nearly a hundred years ago Fitch, in his lectures on teaching at the University of Cambridge, asserted that the main reason for teaching some branch of physical science was the processes by which the truths of such science are investigated, and the faculties of mind which are exercised. He mentioned selective observation, handling objects, trying experiments, questioning

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1. The figures throughout the text in square brackets refer to entries in the Annotated Bibliography and the Supplementary References at the end of this publication.
 2. The group accepted that 'qualifications for the job' often required in practice some compromise with educational principles.
 3. And the group considered essential components of any such system to include the kinds of attitudes to problem-solving and a basis of experimentally derived knowledge, both of which should be the outcomes of a science course.

matter and nature, waiting and watching, inventing tests ... The student must have 'no wish to twist the facts into a particular direction. His theory or final generalization when it comes must have been actually suggested by the facts' [387, p. 400]. Fitch interpreted the term 'the laws of nature' as a belief that what has proved to be uniform in our experience (observed facts) will continue to be uniform under the same conditions; we must take these facts for granted, and not expect them to be modified to suit our will [387, p. 405]. Apart from replacing certainty by varying degrees of probability (which include such certainty as in practice to be indistinguishable from absolute), there have been few, indeed so far as I am aware no, significant modifications in any of the many descriptions of 'the process approach'.

Fitch was arguing for the addition of aspects of the physical sciences to the then usual nature study or natural history, and there can be few now who would question that in the primary school the 'process', very much as described by Fitch, is more important than the content. Which is not, however, to say that content is unimportant. The problem is, rather, which of all the many questions arising from the observation of natural phenomena and which can be used to give young children practice in the 'process' should be selected for study.

Fitch was not a scientist, but there was strong support for his views from many of the leading scientists of his time. In 1870, T.H. Huxley, giving evidence before the Devonshire Commission on Scientific Instruction and the Advancement of Science, said '... scientific teaching ought to be made a fundamental part of all primary teaching in the kingdom ...' [397].

So what are the objectives in primary science? I shall try to summarize the writings of the past twenty years or more.

- To teach the child how to tackle some of the questions that arise from observations of his own environment.
Why is the sky blue? What causes the wind? Why do bees visit flowers, and what do the flowers get out of it? Why does my bicycle ...²
- To sharpen the powers of observation of the child.
Yes, but is the sky always the same blue? If you go to buy blue wool, you find that there are all kinds of blue.
- To direct the attention of the child towards matters which are significant to him, and to the society of which he is a member, more than, unaided, he realizes.
We can harness the wind to do useful work for us; we can 'farm' the bees and use their surplus honey as food; we can slow down rusting and so conserve material. Certain groups in society have special responsibilities and the child himself may become an engineer who will invent better ways of harnessing the wind, or making the devices which harness it. Even if he does not, his life will be affected in several ways by those who do.
- To make a start on the process of science-concept building, in other words of acquiring a science vocabulary, not by definition but by experience.

-
1. The group repeatedly emphasized that, although based on observations of natural phenomena, observations of human exploitation of those phenomena are at least as important. Science penetrates into many areas of the curriculum and is itself penetrated by many areas. Integration - when it is natural and not forced or contrived - of the sciences themselves can have an important bearing on the readiness of pupils and, not least, teachers to operate in this mode over a wider area of concern.
 2. Questions should be realistic to the child, and so should the language used in discussing and tackling them. H.H. ten Voorde submitted a paper outlining the salient features of an important educational experiment in the teaching of chemistry in five Netherlands high schools which cast much light on this problem.

It is here that the main problems arise. The meaning of the word 'metal' grows at each stage of formal education. At what stage should it embrace, say, mercury? And how important is it that a child should not acquire from his primary science a notion of 'metal' that excludes mercury? It is this kind of question which has led many secondary teachers to say that science is better left to them, that it will be so badly taught in primary schools that much of it will have to be unlearned at secondary school. Harlen's chapter of this book looks at this question again.

In this chapter we are concerned that the aims should be realizable in practice, not with the organization of science in the primary school. However, it has to be remembered that whilst there are primary schools which include science as a subject in their time-table, many teachers are never teaching history, geography, science, mother-tongue, etc. as such. They are, rather, weaving strands of all kinds into the daily activities of their children, and we would certainly regard science as one of the essential strands. The National Association of Headteachers (of England and Wales) has said

In schools for younger children, integration of these various subjects can be achieved almost at will: for instance, make a batch of raspberry buns - practical skills, number, economics, science, language are all used [399].

I should certainly have added 'aesthetics' myself.

Peter Evans, head of an English primary school, recently wrote, in a prize winning essay, of his curriculum innovation labelled 'Technology'. He stated his objectives as

1. Motivational: to encourage the child to regard participation in practical science-based activities as being interesting and enjoyable.
2. Conceptual: to provide the child with concrete experiences which assist him to perceive the relationships between mathematics, science, and technology.
3. Creative: to provide work-opportunities which produce an end-product which serves a useful practical purpose.
4. Intellectual: to introduce the child to the intellectual demands of technology which might be summed up as 'the acceptance of a challenge - investigation - exploration of possible solutions - selection - design - construction - assembly - operation - appraisal' [99].

Which allows me to add two more of the objectives to be aimed at in teaching science to young (and for that matter older) children. It should be fun, and it should encourage a feeling for the romance and adventure of science.

But there is a third objective to add, at least as important as any and, although it is implicit in much of the above, it needs to be made explicit. It becomes the major consideration in the case of those pupils, who in world-wide terms constitute the great majority, whose schooling in science ends at 14 or earlier. I am referring here to the role of science education in giving pupils the will and the ability to contribute to local, regional, national and international concerns. Whether, by way of emphasizing this rôle, it is called 'Environmental Science' or not, this is certainly an outcome which any educational system is entitled to expect. It is not surprising that so many of the recent science programmes for this age-group have increasingly given priority to this in their choice of content. We have, of course, to be careful not to so simplify what are often matters of complex decision-making that the child acquires a grossly distorted view of things. We are setting the child on the road; he has much still to learn, whether at school or elsewhere.

PURPOSES OF SCIENCE EDUCATION IN SECONDARY SCHOOL

The British headteachers said 'But as children grow older and able to look further and further afield subjects jostle for a place in the curriculum, and there is need to establish an order of priority' [399]. Eisner has pointed out that a substantial proportion of new curricula has drawn content from the major academic disciplines. 'Until recently', he says, 'no one challenged the

goal of teaching students the concepts and procedures of chemistry, anthropology, or mathematics ... How could learning to think like a scientist be bad?' [383, p. 4].

Layton identified three stages in the development of a school subject. In the early stages, its attraction for learners and teachers lies in its pertinence and utility; gradually its academic status grows and its internal logic and discipline become increasingly influential in the choice of content, finally, its students are initiated into what has become a tradition and their attitudes approach passivity and resignation, 'a prelude to disenchantment'. He suggests that science has reached the last stage, and asks whether or not the time has come to broaden the objectives to include an understanding of science in its external relations with technology and society [193, p. 11-12].

By far the most popular world-wide view seems to be that the aims of science in the early secondary years - the first two or three - should not differ greatly from those of the primary stage.

Typical of a number of statements of objectives for this stage is the one which was the foundation of the Scottish Integrated Science Project [436]. Yet none of the objectives listed actually requires the integration of science. Meanwhile, the Institut für die Pädagogik der Naturwissenschaften (IPN) curricula in biology, chemistry and physics draw on neighbouring subjects and use them as frames of reference [400, p. 22-7]. For example, the IPN Biology Curriculum uses, as its central reference points, man's understanding of himself¹ and his comprehension of the physical and social environment, and draws on chemistry, physics, sociology and cybernetics, as well as morphology, physiology and ethology. The Scottish objectives, then, have not given us reasons for integrating (rather than co-ordinating) science in the early secondary years.

(A word about 'the fundamental unity of science' referred to in the first conclusion of the Varna Congress. I do not propose to go into the familiar debates about this term, only to state my own doubt whether they have any great relevance when we are talking about how to teach science to boys and girls of 11, 12 or 13.)²

It is common practice, after the first two or three years of secondary education, for pupils to choose from among various science possibilities, and in extreme cases to do no science, as such, at all. It is in everyone's interest that such choices should be informed, and the way to ensure that this is so is to ensure that what is done before the choice is made covers at least some recognizable elements of both the physical and the biological sciences. It is not only the pupils who need this, but also the teachers.³ Of course, this can be achieved, probably more efficiently, by teaching physics, chemistry and biology from the start (co-ordinated here and there, of course). But if science subjects are to be taught in the manner Fitch described, and which every recent science-teaching project has attempted to exemplify, then to do this requires either more time

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1. In a paper submitted to the Group, M.S. Al Rashidi makes a powerful plea for a Man-centred programme. 'A child must learn about himself, as well as about science.'
 2. There was some acceptance of the at least plausibility of a suggestion that early integration followed by later specialization was contrary to the way in which children - and people for that matter - learn, i.e. that if we thought first about how children learn, rather than the demands and traditional shape of higher courses, we might end with the pursuit of clearly identifiable courses, perhaps as physics, chemistry and biology, and move towards integration later. There is, so far as the group knows, no hard evidence either way.
 3. Nevertheless, whilst it is true that all disciplines at the higher (university) level have some unique organizations, this must no longer be allowed to dominate school programmes.

than many consider it right to claim, or an omission of more detail than many science teachers can accept. Hence the significance of the first Varna Conclusion.

Another aim in introducing integrated science at this stage may, I suspect, be associated with the changing perceptions of the rôle of the teacher. No longer behaving as the know-all, but rather, even if he does know it all, concealing the fact, the teacher joins with his pupils in discovery. Discovering together, teacher and pupil, for at least some of the time, may well be more conducive towards the achievement of some of the broad aims in Unesco's World Survey [455] to which I referred - always provided that the teacher himself has some skill in the process of scientific discovery, and it is not unreasonable to expect anyone who has pursued any science course into higher education to have that. Unfortunately, although that may be a not unreasonable expectation, it seems to be far from always turning out that way in practice.

We come now to the later stages of secondary education, and it is here where the battle rages, for it is here where what was said at Varna (Conclusion iii) is certainly now, and indeed it was then, incomplete. Whether overtly or not, the content of the course will not be left to collaboration between the science teachers and other specialists. It is here that the 'customers' for the output of the schools begin most insistently to make their demands known. Higher education and employers demand more or less specific qualifications, which is no doubt why, or at least one of the main reasons why, Varna (Conclusion iv) is so non-committal.

Schools cannot ignore these pressures, and indeed insofar as they are more often towards specialization than integration many, perhaps most, teachers of science in the later secondary years would not wish to do so even if they could. However uncertain may be the relationship between competence and qualifications, what can be read at a glance is qualifications; judgements about competence take longer and are more complex, and whether we like it or not, the pursuit of qualifications will in practice continue to be a major influence in the later stages of science education as far as I can see into the future. What we have to keep on trying to do is to demonstrate that, on all counts, this is not enough. A modern society needs, as never before, specialists, but specialists who accept their responsibilities, not just to their specialism and to their fellow specialists, but to all of us - and to those as yet unborn. Hence it seems to me that whilst all the aims already outlined remain relevant to this stage, we have to add this direct preparation for what comes, or might come, next.

I have for many years summed this up for our British science teachers by saying that what we do in science in our schools should give every boy and girl real experience in three major areas

1. Science for the enquiring mind; knowing what he can of what our knowledge and understanding is, and of how it came about, and how it is still advancing.¹
2. Science for action. Knowing how science increasingly gives guidance about what we can do, and what we should be wasting our time and resources to try.
3. Science for citizenship. That knowing we can do it does not decide whether or not we do. There are many other factors to take into account before we do decide.

Whilst it seems to me that these requirements are in the long run most likely to be met by an integrated course (which allows, as an integral part of it, for pupils to follow special topics arising from it), there are many who see cross-linking of the separate sciences as more realistic. For a forceful statement of the case against integration, I would recommend an article by Chapman [55]. However, the trouble about cross-linking or collaboration, as opposed to integration, is that so many pupils drop one or more of the science subjects.

1. This is the pursuit of knowledge and understanding for personal intellectual fulfilment, whether it has any 'outside' value or not. We should all be given enough opportunities to savour it to know how satisfying it can be.

Such integrated science courses as have been developed for the later secondary years have in the main been aimed at providing a terminal course for those whose future employment will be in other fields, pertaining, as V.L. Parsegian said at Varna, to the education of economists, businessmen, political scientists, government specialists, writers and so on. In such cases, the main objective is to explore the interaction between science and society in many of its aspects, ranging from health and safety to cybernetics.

There have, however, been some brave attempts at integrated courses intended for those who have the potential to pursue further their academic studies in one or other branch of science, or engineering. In the United Kingdom we have, for example, the Schools Council Integrated Science Project for the able 13 to 16 year-old pupils, and the Nuffield Physical Science Project for the 16 to 18 year-olds, as the major ones. There are others which, whilst centred on one or the other of the three traditional science subjects, veer strongly towards the engineering aspects.

All such courses claim amongst their objectives all those we have already noted, including adequate preparation for specialized studies later, and add one or other of two more either that they reduce the chance of premature, possibly mistaken, specialization; or that they hold out a better chance that more students will be attracted to further studies, and careers, in 'shortage' areas. In other words, they aim to widen the knowledge of the scientifically able pupil about the options available to him by giving him some experience in fields not usually treated in any depth, if at all, in the usual run of science courses. A worthy aim, but of course these new fields are not only new to the course content, they are also new to the great majority of science teachers.

I detect signs, although they are faint ones, that here and there things are moving forward a little from the situation described by Clark in referring to the acceptability, in 1968, of an integrated course for New South Wales secondary schools: 'Unfortunately this fine course has little hope of being considered a suitable matriculation unit by the conservative universities and as a result its life is probably limited' [269].

So the best I can do to sum up the objectives of science courses at this stage is to say that they try to do, or should try to do, two things. Increase the competence of pupils, all pupils, in all the educational aspects of science we have considered; and ensure as best they can that the pupils gain the qualifications they need and are capable of getting. How the two can be brought closer together, so that the one does not have to be sacrificed for the other, is a matter which should continue to exercise us all.

It is my personal opinion that the enthusiasts for all-out integration of science in secondary schools - a core of science, unified in itself, and cross-linked with other subjects - will for several if not many years to come have to take comfort from a trend that is already becoming evident. Feeling themselves perhaps under threat, teachers of the specialist subject disciplines are more and more broadening their perception of what constitutes 'biology', or 'chemistry', or 'physics' at school (and indeed elsewhere) and moving towards the more comprehensive aims of the integrationists.

PURPOSES OF INTEGRATED SCIENCE COURSES IN HIGHER EDUCATION

Finally, and briefly, I have tried to extract, from what has been written about them, the objectives of those integrated science courses that have been developed for use in higher education. It is, of course, a natural property of any discipline that as it progresses its field of activity expands and that two processes occur. On the one hand, it collects under its wing, in a kind of merger, a number of what were largely autonomous 'subjects', and this happens because it becomes apparent that the concepts that have proved, or seem likely to prove, most reliable in the various subjects are coming to be seen as sub-concepts of those which contain all the subjects. This has happened in biology, in chemistry, and in physics. And the question of where to stop, when we are talking about teaching, is much more closely related to practicalities than to philosophy. It is certainly true that to climb Everest requires all the skills to be

brought into play which are only required one or two at a time in tackling lesser heights (plus no doubt a few more), but that is not to say that the way to practise those skills is by climbing Everest.

On the other hand, the reverse process takes place and a discipline gives birth to embryo 'subjects', which it nurtures as its offspring until the child is ready to leave home for a more or less independent existence although, like most children, still anxious to keep an eye on what the old folks are up to, and not above borrowing or lending as the need arises. In time it may well return to the fold and become truly integrated once more into the family.

Science education has somehow to reflect both trends. The Open University aims in its Science Foundation Course to demonstrate the unity of science as well as its diversity, showing what is common to all the disciplines as well as what is special to each. The course also aims to teach science in its social context, claiming that it is alone among universities in attempting to teach a main science course in this way [361].

SISCON (Science in a Social Context) is producing material for use in higher education 'in the conviction that it is appropriate to the education of scientists, and not only to those doing generalist degrees of the "Science and Society" kind'. The aims of SISCON include those of Contemporary Natural Science (CNS), so well expressed by Reif [427], but how much further they go is indicated by another observation from SISCON:

It is now a commonplace to say that the conventional scientific education offers the graduate no resources for dealing with the moral choices which he will face in life, nor for identifying those which are often concealed from his view [457].

CONCLUSION

Let us end with an attempt to sum all this up in a 'job description' for science education; each item to be prefaced by the words 'To attempt to'

1. give all people an understanding of the nature of science, of its role in contemporary society, of its potential and of its limitations as a guide to action
2. give all people an understanding of how science comes to make its statements with various degrees of doubt and certainty
3. do this in such a way that it produces people who have, above all, learnt how to learn, and are able and, as far as possible, willing, to go on learning throughout their lives
4. teach people to be responsible citizens - to themselves, to their fellow men, to the whole biosphere
5. identify and foster those who have the potential to carry special responsibilities in science and science-related spheres of human endeavour - the scientists, the engineers, the communicators, the technicians, to do it in such a way that, to quote the words of one of the best known hymns in the English language, 'We are not divided, all one body we'.

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See also [15, 36, 37, 42, 64, 112, 269, 270, 271, 383, p. 56-67, 402].



Why does a bubble ...?

3. The case for teaching science as a unity

Victor Showalter

Summary of plenary paper

'Teaching science as a unity' is assumed to mean that all science, as a human endeavour, is taken as the source of educational objectives and learning activities, and that the traditional boundaries among the separate sciences are minimized considerably for these purposes. Although it is recognized that there are arguments against doing so, this paper focuses only on arguments in favour and hopes to provide 'ammunition' for the committed to use in trying to influence more conservative colleagues. The prime consideration must be the student, and the discussion confines itself to the pre-specialization level of education, often called general or liberal education. This level may extend only to age eleven in developing countries and perhaps to eighteen in developed countries, although world-wide trends are toward extending this period.

PHILOSOPHICAL ARGUMENTS

These revolve around the central idea that science is a single unique human endeavour. Science is one of several ways of knowing, and the separate sciences differ only in degree, not in kind.

1. The nature of scientific knowledge is consistent across the various sciences and sets science apart from other ways of knowing. Scientific knowledge is tentative, so that 'truth' and 'proof' are not legitimate in science. It is based on public evidence as contrasted to private evidence which need not be shared or replicated by others. Science knowledge leads to probabilistic, as contrasted to absolute, predictions.
2. A common set of processes is used in generating new scientific knowledge. There is probably no single process which is unique to science, but taken as a group they are. These processes essentially do not change with time; unlike the knowledge of science, they are permanent. Although the processes have developed to greater levels of complexity and power, they can be used at various levels of sophistication and are the same processes as those used by Galileo 300 years ago.
3. A common set of constructs or invented concepts serves as the elements from which science knowledge is built. However, the concepts of field, entropy and equilibrium are no more powerful than the concept of phlogiston, and may live and die in the same way.
4. A common set of values underlies all science. 'Objectivity', once claimed to be value free, is now seen as the product of seven values: longing to know and understand, questioning of all things, search for data and their meaning, demand for verification, respect for logic, consideration of premises, and consideration of consequence. These values represent the ideals of science, and are treasured, but they are not the sole property of science.

5. In mission-oriented research, the boundaries among the special sciences tend to dissolve.
6. There is only one world and there are human preferences for more holistic and less fragmented views and explanations of that world. Apart from being personally fulfilling, a holistic way of knowing is somewhat of a guarantee against acquiring an incorrect or distorted understanding. A unified view of natural phenomena is inhibited by getting too close or too specialized, and one needs to stand back in order to perceive the whole.

PSYCHOLOGICAL ARGUMENTS

These centre on the importance of the human learning process as a rational co-determiner of science curriculum.

1. Overall programme objectives which lead to actual classroom objectives can be directly derived from a philosophy which views science as a unity and a psychology which acknowledges the importance of the learner in shaping these objectives. The various dimensions of scientific literacy are not only entirely consistent with our philosophy of science, they are also consistent with our understanding of how people learn science.
2. The number of major learning objectives can be kept relatively small and limited to truly important aspects of science.
3. Learning in multiple contexts (which typifies most approaches to teaching science as a unity) facilitates transfer of what has been learned. Thus if a student were to learn something about the concept of equilibrium by way of examples from a number of fields, he would be psychologically better prepared to use the concept in a real life situation than if he had learnt it only in chemistry. The same is true of the abilities, say, to interpret data and to manipulate electronic apparatus.
4. The number and kind of learning modes available for use in the classroom are expanded. Because teaching science as a unity is a departure from tradition, teachers are not so bound to the modes that have become standard in the conventional sciences.
5. The format or structure of learning units is opened to variation which can accommodate individual learner differences and thus extend interest and motivation. Again, since teaching science as a unity is non-traditional, there are fewer forces tending to impose traditional formats.

PRAGMATIC ARGUMENTS

These focus on the empirical confirmation of desirable outcomes of school science. The problem is that although there have been studies on the practical effects of teaching science as a unity in a number of countries, the studies for above the junior secondary level are limited to the United States of America.

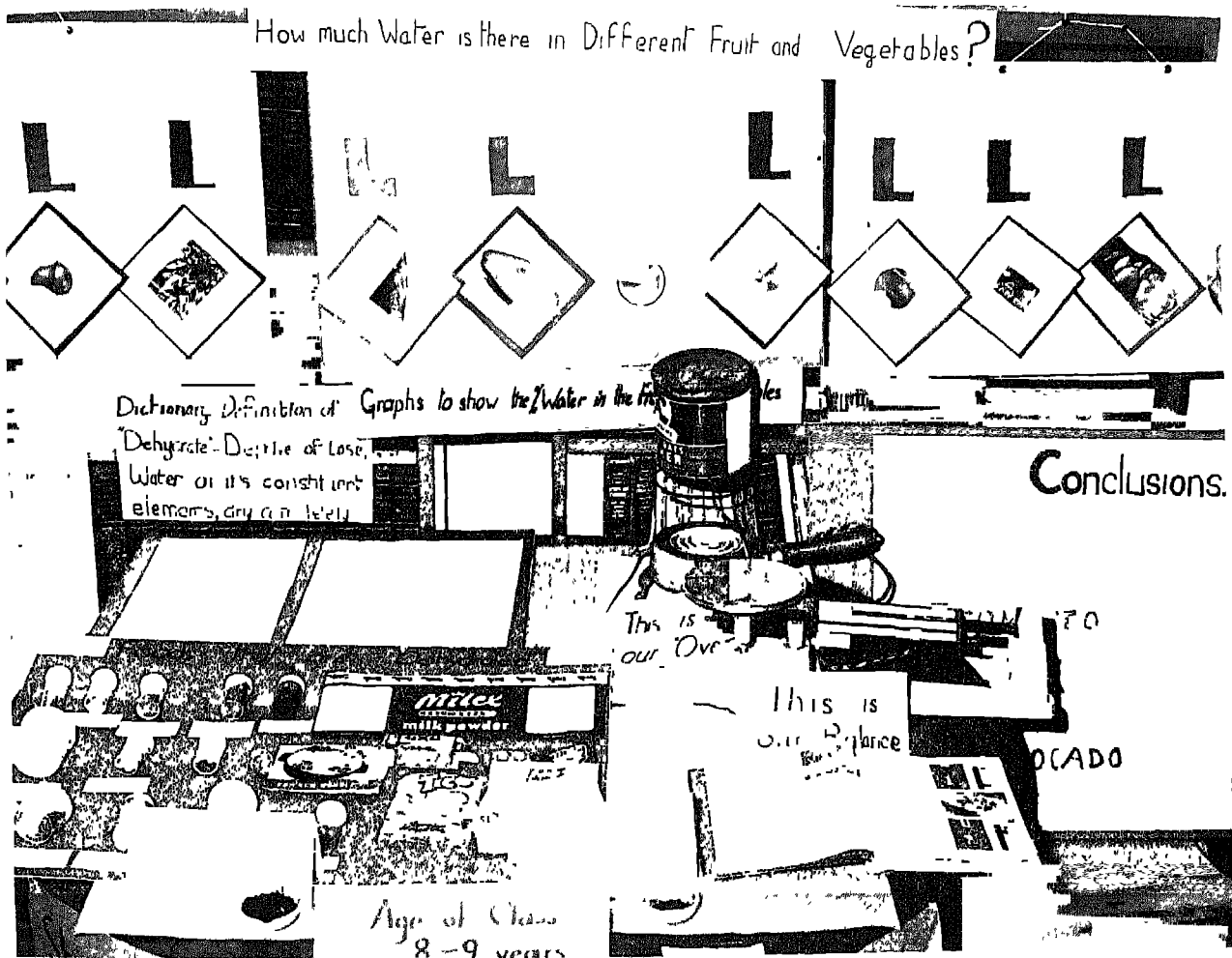
1. Student performance in subsequent college and university science courses is as good as or better than that of students who have studied science as separate subjects.
2. There is greater student interest as indicated by increased elective enrolment in science courses.
3. Enhanced scientific literacy. Students who have studied science as a unity seem to score higher on tests of scientific literacy.
4. There is renewed teacher interest in teaching and learning science.
5. There are new levels of inter-teacher co-operation and acceptance of a common set of goals.

It must however be stressed that the evidence is still at a level where it must be interpreted with caution.

INTEGRATED OR FUSED?

In the discussion which followed the lecture, an issue was raised which relates to the matters discussed by D'Ambrosio's working group. When one is talking of teaching as a unity, does one stop at science and if so, why? Dr. Showalter's view is that an integrated unit of teaching is one which fuses not only science but the other realms of meaning as well. Thus the Federation for Unified Science Education (FUSE) distinguishes between unification and integration. Science is seen as a whole. Integration across realms of meaning can cause problems. For instance, Darwinism, as with all of science, must be subject to refutation, Genesis, which belongs to the realm of synoptics, is not. So they cannot both be taught in the same class without disharmony. Integration from time to time may be worthwhile, but as a steady diet it has dangers.

The full text of this paper (25 pages with bibliography) is available from the author



Integration of science, language, mathematics, craft, consumer awareness....

4. The relationship of integrated science to other subjects in the curriculum

Ubiratan D'Ambrosio

SUMMARY OF WORKING GROUP PAPER

It is useful to distinguish systematized knowledge from the process of acquiring knowledge, the latter being of most concern in schools. With a fully integrated curriculum, scientific creativity (one of the objectives of teaching science in schools) is developed in relation to the environment, both socio-cultural and natural. Integrated learning is the acquisition of a global view of natural phenomena, with strong inputs from society and culture. The mental processes which generate a scientific attitude and an understanding of science may be represented as in Figure 1. Language is

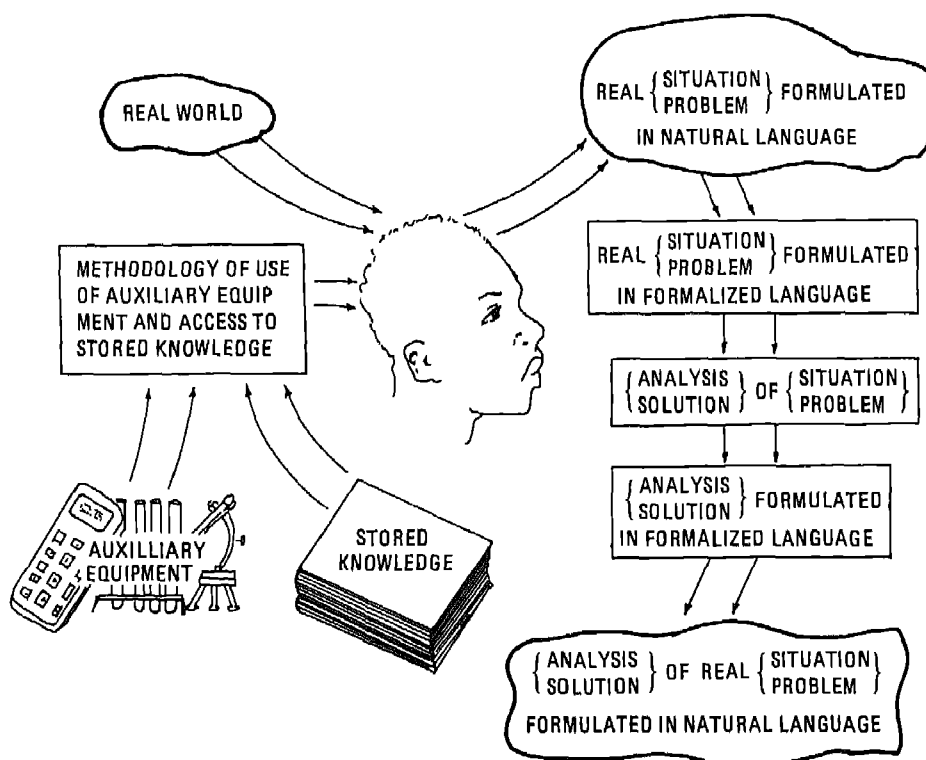


Figure 1. The mental processes which generate scientific attitude and understanding of science

the chief process by which knowledge is acquired and deserves a special place in the curriculum, certainly above content for its own sake.

Although the acquisition of knowledge (content) is one of the objectives of education, it should be seen as a result of the educational experience, instead of providing the guiding framework, as has traditionally been the case. The process of scientific discovery, which should dominate science education, does not flourish when a curriculum is programmed into disciplines according to content criteria. Figure 1 shows, instead, an open situation where accumulated knowledge is brought in as it is needed.

Accordingly, information retrieval systems are needed. Such systems began with the invention of printing, but today we also have access to electronic systems, and I see no hope of bringing advanced science and technology to useful and ready access, especially in developing countries, unless we shift the pattern of education to a retrieval based approach. Of course, much of the stored knowledge has been stored in the individual's memory, and can be retrieved by remembering, but this is only one of a number of retrieval techniques. Others are computers (see, for instance, the Chelsea Science Simulation Project), home-computerized television, and alpha-numeric pocket calculators. The use of such strategies is nearer in the future than we realize, and it is appropriate that a Conference reviewing world trends, like the Nijmegen Conference, should be concerned with the issue.

In the past, it was difficult to bridge the gap between the real world and science since mathematical modelling could not be achieved, except in a token way, at the elementary level. Now for the first time science education can be changed from a purely observational and descriptive pattern to quantified reasoning, the full essence of the scientific method, as a result of the availability of hand-held calculators.

It now becomes possible to move beyond the learning of mathematics for its own sake to 'useful mathematics', mathematics as a process used by scientists in the analysis of nature. It has been found that little integration of mathematics and science is taking place, but several exceptions exist, for example in Ghana and Brazil, and regionally in Latin America by Unesco. In particular, the most comprehensive work in the development of mathematics units with an integrating flavour has been carried out by the Undergraduate Mathematics and its Applications Project of the Educational Development Center at Newton, Massachusetts.

In Brazil, the Institute of Mathematics, Statistics and Computer Science of the State University of Campinas is developing units for elementary and secondary schools, these units touch on critical issues of the traditional curriculum and can be inserted into the existing curricula. The underlying aim is to bring science and mathematics into a close relationship with other school subjects assuming an intuitive pre-modelling approach, that is, an informal capability of recognizing mathematics in real situations. In Brazil, with some 25 million children in elementary school, the logistic problems of replacing curricula en masse would be insuperable and the implementation would be ineffective; but the 'stealth method' just described, similar to introducing a perturbing effect in the official curricula, does seem to be effective in motivating students, teachers and parents towards more change.

The paper gave details of the units and the strategies used for teacher reorientation; and Professor D'Ambrosio reiterated his view that urgent efforts are needed if we are to be more successful than in the past in bringing science and technology to the population, especially in developing countries.

The working group in particular focused on the concept that the environment, in both its socio-cultural and natural aspects, should be a most important unifying factor; and the need for the preparation of teachers for integration, either as full integration of all subjects or as a milder co-ordination of science with other school subjects, to depart from the traditional pattern of teacher training or recycling, moving towards an in-service pattern, more dynamic and responsive to the teachers' motivations and backgrounds.

REPORT OF THE WORKING GROUP

RATIONALE FOR AN INTEGRATED CURRICULUM

D'Ambrosio has suggested that education attempts to provide a knowledge of the world. We have usually attempted to do this by dividing this knowledge into a system of studies which we entitle subjects. This works very well in breaking down the enormous amount of information which must be acquired by pupils as they progress through the education system with increasing maturity which comes with age, and science is one element of the system. However, *analysing* knowledge in this way, and presenting it in the elements that are called subjects, does not help students to *synthesize* their learning into the global view, to use D'Ambrosio's term, that is our aim. Integrated science is a step in the direction of restoring, at least at some educational levels, an integral view of the environment, but science is only one of the elements, and by itself cannot provide an understanding of the 'real world' outside school in its full natural and socio-cultural context.

As scientists, we must also welcome the contribution that can be made by other disciplines to a greater understanding of science itself and of the rôle played by a study of science in knowing the world. At the same time, those other subjects would benefit by making use of the techniques that science has developed for its own process of education.

The group therefore agreed with D'Ambrosio that in education there should be integration affecting both content and activities as they illustrate important concepts and processes. A seminar in Nice in 1970, reported by Pierre-Bernard Marquet, identified four ways in which the disciplines at school level could be made to interact: the multi-, pluri-, inter- and trans-disciplinary approaches. The differences lie in the degree of juxtaposition, overlapping, integration or interaction of content and methods from two or more disciplines.

Integration is not, however, a simple matter. Whether across scientific disciplines or across the whole curriculum, the synthesis made by the individual depends very much on the ways in which he develops understanding through his experiences of the world. Generally, however, educators can draw on their knowledge of psychology, and must bear in mind the maturation of the child.

As with any kind of educational innovation, in planning for an integrative approach it is essential to take account of the socio-cultural background in which a particular educational system operates. Particularly in developing countries, there are very strong forces at the level of decision-making, and these forces are strongest where the control of education is centralized. Political considerations come into play, for or against integration or the introduction of extraneous technologies. Social class mobility also tends to cause parents to resist integration and the introduction of medium and advanced technologies; and examinations reinforce this kind of resistance, since they are seen as the passport to social advancement, and are slow to respond to innovation. In short, there is a tendency of society to cling to its established patterns, and these patterns must be borne in mind when planning strategies for integration. D'Ambrosio described a strategy developed in Brazil which faced such problems.

TEACHERS

Whatever system of education is adopted, the key factor must be the strength of the teaching force. In this group, as throughout the Nijmegen Conference in groups with a diversity of briefs, this was asserted very clearly. In no case is the key role of teachers likely to be more evident than when we wish to undertake the intricate exercise of integrating across subject boundaries. The attitudes needed both for teaching in an integrative manner and for establishing a high level of co-ordination and interaction among subject areas within every school depends to a large extent on the individual teacher. If the teachers have not been well trained, there will be misuse, however carefully a curriculum has been worked out, however detailed and scientifically accurate are the text books, work sheets, equipment and operating instructions, however adequate the physical facilities.

It seems generally agreed that the teacher must be taught in the same way he is expected to teach, and that the only effective way of learning how to teach is by teaching. Accordingly, if teachers are to be prepared to teach an integrated curriculum, their own training and curricula should be based on a global environment, from which will come the problems they will face in their day-to-day classroom situations. The training must be carried out by a team which includes scientists, educational psychologists and sociologists, educators, economists and other professionals as necessary; student-teachers especially should follow a course of self-education.

A very important issue is the selection of candidates for the teaching profession. The present situation is worst in the selection of primary teachers, a job that, it seems to be felt, can be done by anyone since his prime function is the transfer of (very simple) knowledge. This attitude is very serious when we remember that the primary teacher usually has to deal with the entire curriculum, and this includes not only instruction but also the educational tasks such as the development of attitudes, the awakening and developing of abilities and skills, and the cultivation of desirable habits. In his job of overseeing the physical and mental growth of children, the teacher is, however, much helped by the fact that young children tend to perceive their world as a whole and an integrated approach should be easier than one based on convenient separation into subjects, as long as the teacher has been prepared accordingly.

At secondary school level, where subject groupings are the norm, both within the school and in at least part of the education of the teachers, new strategies are needed if pupils are to recognize a global picture of reality even if specialization is retained. Indeed, total and absolute integration is not advocated, since today's teachers need to keep their individuality, but more co-ordination is required. Team work is an essential strategy which should receive attention in both pre- and in-service courses.

However imaginative and appropriate are teacher-training courses on educational grounds, the trained teacher in many countries faces serious problems arising from the socio-cultural structure and administrative organization, often so rigidly organized and centrally controlled that even enterprising teachers find it difficult to be flexible and innovative. They are not helped by the approaches of inspectors/advisers, who are often too restrictive and fault-finding when they would be more influential as advisers and disseminators of information and ideas. Within the school, the ordinary teacher can be helped a great deal by a stimulating administration, a head teacher and his deputy who see themselves as the servants of education and not the other way around.

CURRICULUM CONTENT

In planning an integrated curriculum we need to distinguish between *content as facts* and *content as concepts*. Even if it were possible, there does not seem to be much point in organizing a curriculum around facts; on the other hand, a curriculum based on concepts is self-integrating and contributes naturally to the global view of the world that we seek. Examples of cross-disciplinary concepts are interdependence, change, energy, continuity and structure, each relevant not only in science but also in history, geography and other disciplines. However, while attempting to build concepts, we may find ourselves caught up in facts in an attempt to provide tangible material in schools. One unfortunate consequence is that examinations tend to focus on 'facts and figures' rather than on the assessment of more important educational outcomes such as modification of behaviour and development of attitudes which will help the young person to adjust in an ever-changing society.

Assuming we are agreed that a curriculum should be organized round concepts rather than facts, we are left with the question of the degree of prescription or flexibility that should be provided by curriculum planners. There are advantages and drawbacks either way. D'Ambrosio has advocated a content-free approach, but we should prefer to use the expression 'content-independent', which might convey more clearly the idea that a suggested content will help the teacher, but that he should be encouraged to be flexible according to his knowledge and skills and the needs of his pupils. The place of content might be illustrated by an old Chinese proverb: 'If you give a man a fish he will eat once; if you teach him how to fish, he will eat always'. Content may be either 'fish' or 'fishing', and the use made by the teacher will determine the failure or success of the

young person in his later encounters with the world. While we agree with D'Ambrosio that content should not be the prime objective of education, we prefer to describe it as a tool for the achievement of educational goals rather than a result of the educational experience.

METHODS OF TEACHING AND LEARNING

As with content, we are in favour of flexibility in the choice of method. While an integrated approach to the curriculum *must* respect and convey the integrity of each discipline and its methodology (including similarities and relationships among disciplines, and their limitations), variety and flexibility in teaching method should be encouraged. However, the beginner would welcome guidelines for his approach while he is learning to adapt to particular classes and classroom situations. There is a risk that the scientist-teacher will overemphasize the methodologies of natural science teaching, discovery-learning, inquisitiveness, questioning, child-centredness and so on; other disciplines may use different methodologies which could be more appropriate in a particular situation, even a science situation; and of course the methodologies of science teaching may well enrich the learning in another discipline. There was consensus that the choice of methodologies must develop relationships among teachers and between teacher and pupil, and that all of them should be actively involved.

Certain teaching methodologies, especially so-called discovery learning, were viewed with caution. Apart from the fact that reliance on a single method is unwise, discovery learning in many countries is not compatible with the influence of examinations, the nature of teacher training, the willingness of teachers to adopt the method, and the socio-cultural climate.

At this point, it may be necessary to clarify that, like D'Ambrosio, we recognize degrees of integration. Subject boundaries will not necessarily be eliminated. What is desired is a new kind of curriculum in which co-ordination and interaction emerge both from the subject matter itself and from the specialisms of the teachers. We hope that teachers will dare to cross barriers, and use or ask for help from concepts, examples and methods which currently belong to other disciplines. Teachers are, after all, members of a team.

LANGUAGE

One of the most important processes in education is communication, and thus language in all its forms, verbal and non-verbal, formal and informal, scientific or literary and common speech, and so forth. In many developing countries, language can pose special problems. D'Ambrosio stressed the way in which language is a vehicle to convey knowledge and ideas, strongly emphasizing formal language as opposed to natural language, and advocated a greater attention to mathematics as a 'finer language'. Although the group did not entirely agree with D'Ambrosio, there was agreement on the general principle that language is a vital element of any human enterprise, and that it includes every kind of expression such as gesture, music, art and mathematics. Language is not only a means of communication between people, it also provides a mechanism of thinking and shaping ideas.

It follows that language should not be treated as just another subject on the curriculum, the responsibility of only certain teachers. If teachers were aware of the broader meaning of language, of the fact that it embraces many ways of expression, and of its role in developing thought, then interaction across the curriculum would be stimulated.

Teachers have to take decisions about when and how to pass from everyday language to the more formal language associated with scientific, mathematical and technical usage. They should recognize the problem in some countries caused by a native vocabulary which is either narrower or wider than the language of instruction. Modern mathematics and its language has widened the gap between mathematics and science, between mathematics teachers and other teachers, and between school and home. In all issues concerned with language, then, it seems self-evident that teachers have to work as a team.

THE IMPACT OF MEDIUM AND ADVANCED TECHNOLOGIES

The introduction and wider use of advanced information retrieval systems in education as advocated by D'Ambrosio was regarded as too extreme. Advanced technology is far removed from the reality of most newly independent and developing countries. Money spent on acquiring classroom aids, audio-visual materials and electronic devices when there are shortages of well trained teachers was not considered wise since, as has been stressed earlier, teachers were seen as playing the key role in education. Further, in a country whose schools are without electricity, much technological equipment is out of the question.

Even in developed countries there are socio-cultural pressures against the general use of hand-held calculators. Although there is as yet no evidence about the appropriate stage in a child's maturation at which he should be introduced to such advanced technology, hand-held calculators were thought to be unsuitable for pupils who have not acquired a sound understanding of manipulation of numbers.

However, it was agreed that intermediate technology should enter the classroom at a level which matches the level of technology in the community. An appropriate sequence would be hobby-type technology through intermediate technology to advanced technology as the child progresses through school, but always with the active involvement of the child. The first stages are represented in the African Primary Science Programme, where children make and use simple microscopes, thereby preparing themselves for later use of more sophisticated microscopes.

In general, then, it was felt that, provided resources were not diverted from teacher education, there should be support for the use of any technological resources which are available and which will help to educate the child; but they should not become the focus for the design and implementation of curricula.

SOME EXAMPLES OF INTEGRATED PROJECTS

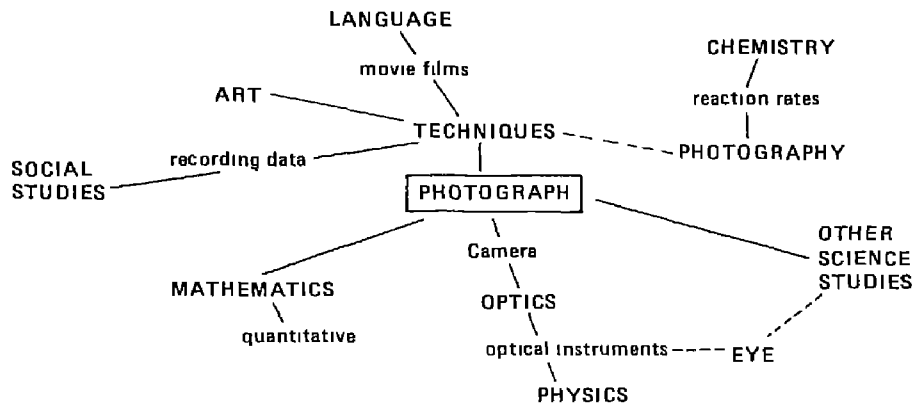
PRONAMEC (Peru) has developed a Conceptual Model for Curriculum Integration which attempts to integrate 'experience generating fields' called psychosomatic, expressive, investigative or inquisitive, and logic-symbolic. The Schools Council of the United Kingdom has a number of projects such as Science in Society, Science Uses Mathematics (SUM) and Science 5/13. In the United States there are Development of Lab Materials to Teach Math through Science Applications, The Use of Art and Crafts (using, for example, Escher drawings), and the Brooklyn College School of Education Teacher Training Model (in which teachers in many different fields co-operate in team projects). The International Clearinghouse Reports list many others. Concrete illustrations from three countries are shown in Figures 2, 3 and 4.

SPECIAL RELATIONSHIP BETWEEN SCIENCE AND MATHEMATICS

A subgroup addressed itself to this issue and, although most of its concerns have been reported above, it seems worthwhile to make a few additional observations and give specific illustrations.

Attention was drawn to a limitation arising out of the composition of the group. It was considered that in a conference of science educators there could be no guarantee that the points of view of mathematics (or other) educators would be adequately reflected. For example it was doubtful if mathematicians in general would put as much emphasis on direct observation and induction (at the expense of proof by deduction) as scientists would. There was a distinct danger that such a group might see integration as the imposition of the concerns of science on the rest of the curriculum.

The relationship of integrated science to other subjects in the curriculum



N B The use of lines, not arrows, to connect various parts indicates the topic may be precipitated from any point or subject area

Figure 2: An integrated project using thematic approach in Tasmania

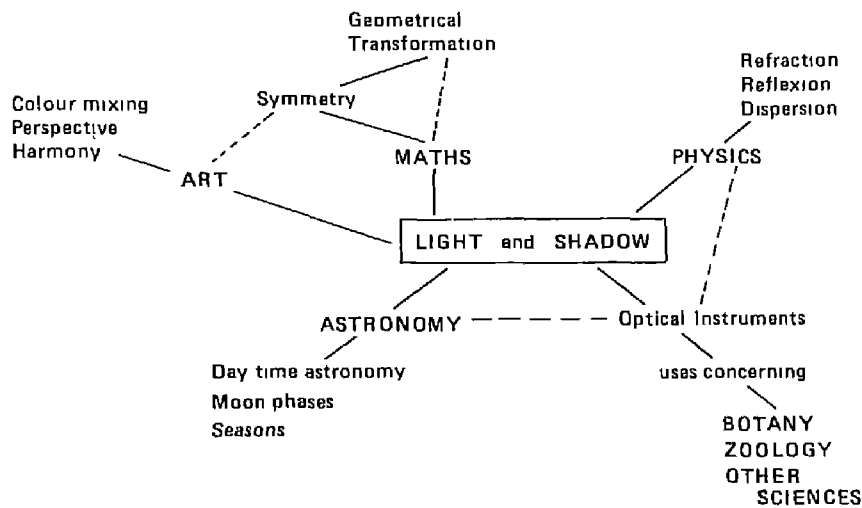


Figure 3: Theme approach to integration of science and other subjects in the curriculum (Israel)

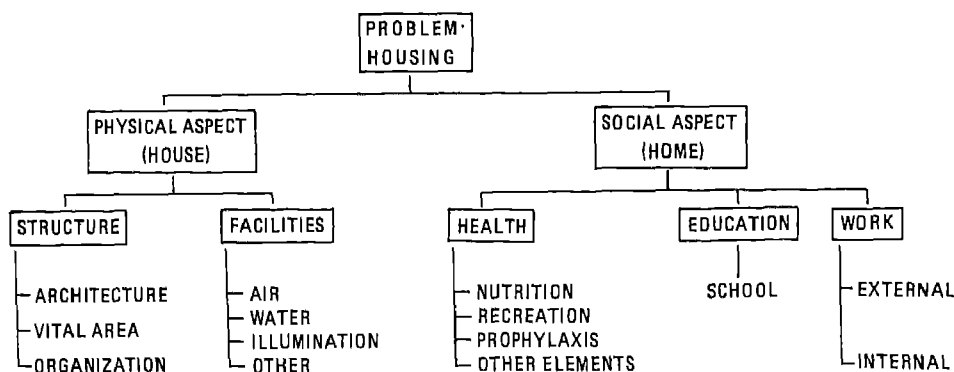


Figure 4 Environmental approach to curriculum integration in Peru

It was considered useful to go through the relatively simple task of identifying areas of overlap between mathematics and science. Topics such as graphs, probability, proportionality, geometric functions were identified and provided a focus for some of the discussion.

A distinction was drawn between similarity of topics and similarity of objectives. It was argued that in graphs, for example, mathematics was more interested in the graph as representing an equation than as representing actual data collected. The latter is of course the primary concern of the scientist. Both mathematics and science teachers needed to realize that the ideal relationships embodied in mathematical models are approximations to, rather than perfect representations of, reality.

Full integration (teaching in a single programme) might be attempted where the objectives (not just the topics) were truly identical. Co-ordination of teaching by different individuals might be a more appropriate aim for other areas of overlap where there are differences in objectives.

CONCLUSIONS

The group was disappointed at the lack of data and identified a need for some strategy of collecting and disseminating information on integration of science with other subjects. At the local level, innovators, decision-makers and education authorities should stimulate co-operation among teachers of various disciplines, and should organize the diffusion of information, especially to teacher training centres.

Simple co-ordination of topics in separate subjects would at least be a start, and it could lead later to active co-operation of teachers and an integrated curriculum. Curriculum innovators and planners should bear in mind that in planning for integration, there should be attention to the methodologies associated with all disciplines, to theories of learning, to a spectrum of strategies of teaching, and, finally, to the place of education in individual, societal and national development.

The full text of Professor D'Ambrosio's paper (22 pages with bibliography) is available from the author.

5. A review of integrated science education world-wide

Sheila Haggis and Philip Adey

Summary of plenary paper

We have identified some 130 curricula that could be called integrated on grounds of both scope and intensity as defined by Blum [270, p. 29-51]. A system of classification was designed in order to obtain an overview of the state of integrated science education in 1978. While details of some courses were not available to us, we believe that the representation has been sound. Quantitative data must be approximate because of the wide variety of approaches, because certain curricula fall into more than one particular category, and because in many cases our access to the curricula has been limited. We have provided no data on implementation since reports tend to be optimistic and, in any case, simple quantification might be misleading. Finally, we have attempted to identify trends.

The speakers illustrated their statements with examples, mentioning a wide variety of curricula from a wide variety of places.

THE STATE OF INTEGRATED SCIENCE EDUCATION IN 1978

The distribution according to age level is shown in Figure 1. At primary level, virtually all science curricula are integrated and they may be under-reported. At lower secondary level, the growth is most rapid. Senior secondary courses may be for the able, for students more interested in the humanities, for the less able, or for those with a special career interest. Teacher education courses are for the promotion of the teaching of integrated science and may be for teachers of either science or general subjects. Some university courses are designed to give liberal arts majors some understanding of the ways of thinking characteristic of scientists; others aim to give future specialists an overall view of science and to bring out the relationship between science and society.

The distribution according to ability is shown in Figure 2. Almost all courses claimed to be for all abilities, or for average ability pupils, but the meaning of 'average' is often unclear. The number of courses for the brighter student seems low when we remember that this includes all college and many senior secondary curricula, and in many parts of the world only the more able are still in full time education at this level. The reasons for the imbalance deserve investigation.

Something less than half the curricula came from developing countries. Some regions, such as Eastern Europe, were under-represented, which suggests an inadequacy in our sources. While most courses are only in the language of their own country, there are some, especially from the United States, which have been translated into many languages. In some countries, e.g. Nigeria and India,

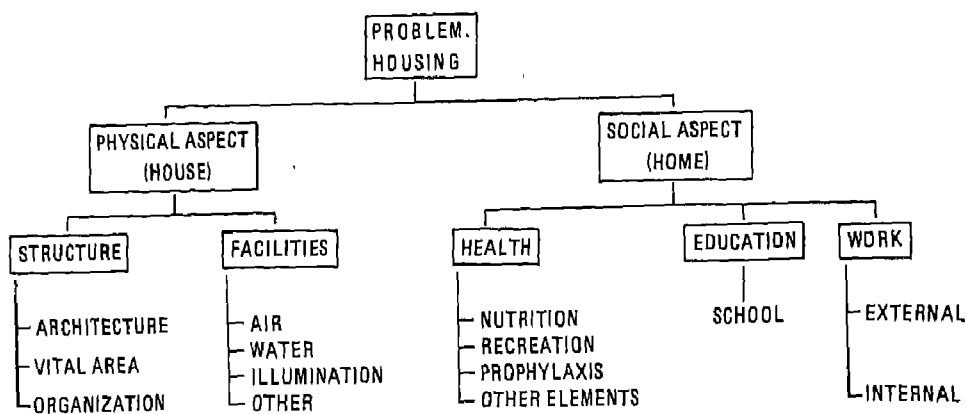


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Something less than half the curricula came from developing countries. Some regions, such as Eastern Europe, were under-represented, which suggests an inadequacy in our sources. While most courses are only in the language of their own country, there are some, especially from the United States, which have been translated into many languages. In some countries, e.g. Nigeria and India,

materials have been produced in a number of local languages.

The distribution according to level of originality is shown in Figure 3, which also shows the proportion of items in the data bank that could be classified.

The initiators of the curricula are represented in Figure 4, but for a given curriculum, more than one agency may be involved. In the school level bracket, we have included only those courses that, although developed within a particular school, have become widely available. The intermediate level includes projects initiated by local authorities and school boards, teachers' centres and educational research institutes. The national level is most familiar; but we have distinguished between federal (national) and state levels because in some countries (such as India, Nigeria and the United States) development may be at either level. The universities category includes both tertiary courses and school courses developed by faculties of science and education.

Distribution according to flexibility is shown in Figure 5, but printed materials are not good indicators of the degree of prescription as it is manifested in the classroom. In a prescriptive course, the teachers' guides are detailed and attempt to minimize the effects of inadequate in-service teacher training and of rapid teacher turnover. Other courses provide a series of units with suggested paths and alternative routes. Almost any course with a textbook must be at least as structured as this since the book is a structuring factor, but we recognize that the teacher imposes his own characteristics. The modular courses provide 'bits' of structured material that may be used by the teacher in a variety of ways. Maximum flexibility is provided by a resource bank of ideas to be picked over by the teacher.

Figure 6 shows the scope of integration. Some physical science and biologically-based courses have been judged to be integrated two-subject courses. Integrated three-science courses include many of the older integrated science curricula for secondary schools. The third category often reflects some aspect of social concern, but we have excluded those courses which, while claiming social awareness as an objective, do not reflect this in their printed material. Other non-science disciplines may also be included.

Figure 7 shows the intensity of integration, but this was not easy to determine. The co-ordinated curricula are those in which one can distinguish 'bits' of the separate sciences, woven together into a continuous curriculum with a structure of its own. A combined curriculum starts with the ideas of the separate sciences, but these ideas become melted together. An amalgamated curriculum is one that has been developed by calling on ideas from the separate sciences as they are needed.

The printed material produced by a project is the most influential link between the project and the teachers. Almost every project was found to provide an overview of philosophy and aims, usually worked out in detail in a teachers' guide. Most projects have some type of worksheet and pupils' books of some sort. Tests and other evaluation material are important in most projects. Some curricula depend heavily on self-instructional materials. Most projects produce their own material, so that only four or five are essentially referencing projects. Courses depending heavily on audio-visual aids seem most appropriate where the influence of these courses is expected to be wide-ranging (as a teacher-training course would be) or where there are special communication problems. We had difficulty in obtaining reliable information about equipment demands although all courses involve some practical work, and for most this is central.

TRENDS

1. Integrated science education is a rapidly-developing and expanding educational field. Ten years ago, at the time of the Varna Conference, there were only thirty to forty integrated science courses in existence. From the one hundred and thirty we found (and we believe there are many others), we have been able to develop Figure 8. The reasons for this proliferation arise from concern about the nature of science, educational concerns and social concerns [40], the last of which came into prominence somewhat later than the first two.

2. There is a world-wide movement to introduce science into primary school education, as a basic ingredient of the curriculum. Almost all primary science courses are based on direct pupil experience with materials, simple inquiry processes, the building of simple concepts, and an awareness and exploration of the environment. This requires a major shift in the rôle of the teacher, and this is perhaps one important reason for the fact that successful implementation strategies have yet to be found. Harlen explores attempts at solution (in her chapter).
3. There is a rapid and widespread development of integrated science education at the lower secondary level. The significance of science education as a component of general education, discussed at the Varna Conference, has found wide-spread acceptance. The pupil's day-to-day experience, of concern in general education, is often best treated in an integrated or interdisciplinary manner. Courses at this level are also based on the extensive use of equipment and concrete materials, and they tend to emphasize depth in a topic rather than the breadth which characterized general science. Teacher training is still a problem, as indicated at the Maryland Conference, but a less acute one than at the primary level.
4. Much greater attention is now being paid to the training and re-training of teachers for integrated science. The Maryland Conference made many suggestions and identified some obstacles and these are being taken into account. In many countries, the involvement of teachers and science teachers' associations in design and implementation is considered especially effective.
5. There is a trend towards greater social relevance in integrated science courses. Both the Varna and Maryland Conferences raised this issue and the emphasis has grown. All forms of science teaching are being affected, but many countries are seeing common core integrated science as the most appropriate response. Lewis (in this volume) has expanded on this issue.
6. An emphasis is now being placed on environmental issues in integrated science courses. This is one outgrowth of the concern for social relevance. The challenges and some recommendations arising from the 1977 Tbilisi Conference are worth reference (and have been mentioned by Dyasi in his chapter). Well before this, however, several integrated science programmes, notably the Australian Science Education Project and the African Primary Science Programme, had recognized the importance of environmental issues.
7. Integrated science courses in science and technology education are now being developed. At the Maryland Conference, Foecke drew attention to the fact that science and technology were distinct but related, and since then there have been attempts to combine these in courses in which children learn skills to solve real life problems.
8. The scope of integrated science courses is now being extended. From the early integration of biology, chemistry and physics (and very occasionally earth and space science) integrated science courses have come to include such elements as crystallography, marine science and health and nutrition (the last is discussed in Raw's chapter).
9. Attempts are being made to inter-relate integrated science courses with other curriculum areas. In attempting to educate through science, it has become apparent that other curriculum areas have an important rôle to play. Chief among these are mathematics and language, as recognized by the primary Yoruba project in Nigeria.
10. Much more attention is being given to evaluation in science education. The Maryland Conference noted that in this area little information was available, but since then there has been more activity at international, regional and national levels. *New Trends in Integrated Science Teaching Vol. IV* [61] is a review of this field.
11. In the design of integrated science courses, the results of educational studies and research are being applied. Courses now tend to be based on knowledge about the way in which children think and learn, their spatial abilities and language development, and their cultural backgrounds and belief patterns.

The full text of the paper (25 p. with bibliography) is available from the authors.

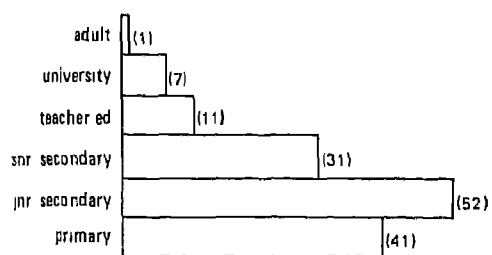


Figure 1 Distribution of i.s. curricula amongst age levels

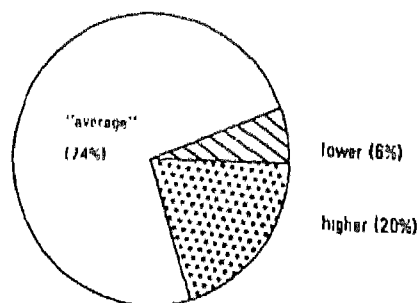


Figure 2 Distribution of i.s. curricula amongst ability levels

- a borrowed, minor changes
- b borrowed, major changes
- c largely original
- d original

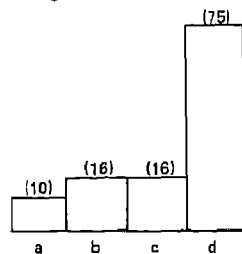


Figure 3 Levels of originality of the curricula.

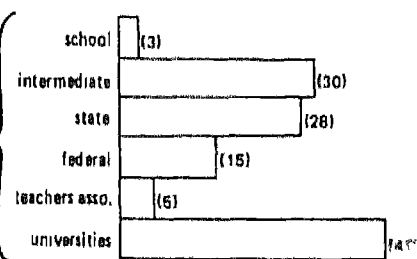
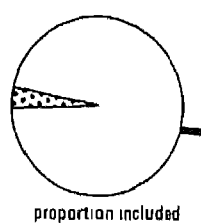
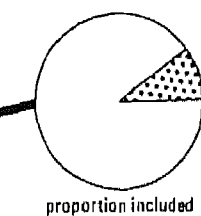


Figure 4 Authorities initiating integrated science curricula

- a: prescriptive
- b: alternative paths suggested
- c: modules for flexible use
- d: resource bank

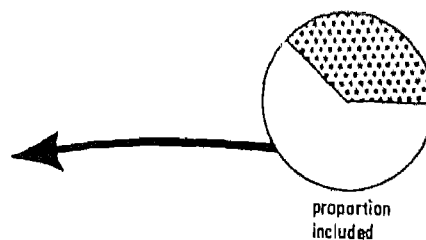
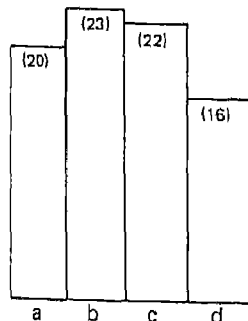


Figure 5 Distribution of curricula amongst levels of flexibility.

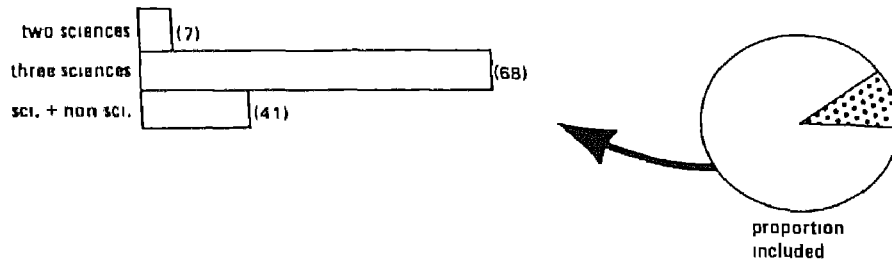


Figure 6 Distribution of curricula amongst levels of scope

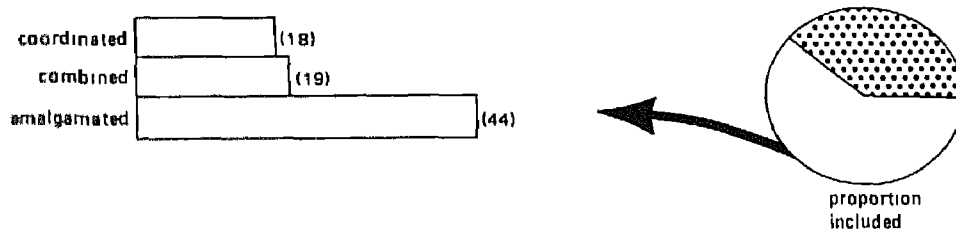


Figure 7 Distribution of curricula amongst levels of intensity



Figure B: The number of integrated science curricula initiated each year since 1961

6. The design and content of integrated science courses

Thomas Gadsden, Paul Becht and George Dawson

The purpose of this chapter is to explore, world-wide, the design and content of integrated science courses developed over the last decade, and to identify trends. The various components of an integrated science programme, shown in Figure 1, will be discussed in turn.

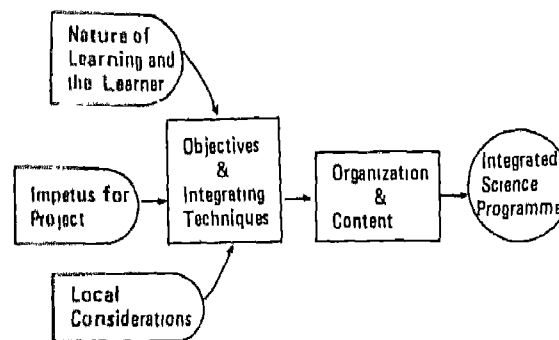


Figure 1: Components of an Integrated Science Programme

IMPETUS FOR INTEGRATED SCIENCE PROJECTS

For schools, as a survey has indicated, projects have been responses to at least five needs.

A need to improve science teaching Some have seen the process of integrating as an opportunity to rethink the teaching process, and to introduce new pedagogical methods along with the integration. In other cases, integration has permitted the inclusion of content not normally found in discipline-centred science, such as interactions of science and society.

Needs of special groups of students Some projects have attempted to meet the needs of low ability students, advanced students, isolated populations, or minority cultural groups. The Biological Science Curriculum Study's 'Me and My Environment' and 'Me in the Future' [199, 201] are for the educable mentally handicapped. 'Turn on Science Program for Native Indian Students' (TOSP, of British Columbia, Canada) attempts to meet the needs of its target, by including such topics as Native Indian Scientific Knowledge, Contributions of Native Indian People to Science, and Man's Interference with Nature [199].

National needs These include increasing literacy, strengthening manpower in technical fields, dealing with national problems such as pollution, and improving citizenship. They may also include the need to reduce the cost of science education or to provide mass general education. In Brazil, for example, when compulsory education was extended from four years to eight years, federal law recommended integrated science, observing that 'separated chemistry and physics courses for the general student are inferior to an integrated course which gives a better global view of science'. The law goes on to describe integrated science as 'presenting science as a story of human progress' and 'involving students in solving problems drawn from the surrounding community' [216, p. 52].

A need for greater relevance Topics having special meaning for target students of Nuffield's Working with Science are Noise, Prejudices and Superstitions, and Automotives [300]. One of many programmes designed to focus on local problems and environments, and to use local materials, is the African Primary Science Programme developed by the Science Education Programme for Africa (SEPA) [199, 201, 300].

Relevant science as defined by Maybury has a 'wide spectrum of objectives ... necessary to satisfy the demands of mass education'. He sees the Integrated Science Program (ISP) and the Environmental Science Course of the Philippines as excellent examples whose objectives are broad enough to allow all students, regardless of ability, to progress successfully toward learnings that are important to them [216].

Several projects have a flexibility that encourages local choice and student participation in the selection of topics. FUSE [299, 438] and the Lower Secondary Science Project (LSSS, Western Australia) [201] have set up resource banks of instruction modules that can be used in an eclectic manner to build programmes for local needs. The Primary Science Scheme of the Territory (PSST, Australia) prescribes curricula organized around Brandwein's *Concepts in Science*, but encourages teacher determination of content and method by referencing materials from four other integrated science programmes [201].

Need to promote the individual growth of students The Schools Council Environmental Studies Project reports that its long-term aim is the 'development of adaptable, perceptive, and confident children, who can grasp a wide range of ideas and absorb information' [225].

At the tertiary level, integrated science programmes have been few, but it is possible to identify at least some of the needs that have stimulated them. First, the need for general education during the first years of tertiary schooling - especially for those students who do not plan science careers, the breadth of integrated science enables them to relate science to their own lives and careers, and provides a more comprehensive view of science as a worthwhile endeavour. Second, the need to train teachers for the use of specific school programmes - Individualized Teacher Preparation (ITP), developed to train teachers for the Integrated Science Curriculum Study (ISCS, United States), could be used either within a college or as a self-instructional package. Finally, the need for career generalists in science, most likely in environmental science and some branches of engineering - Northwestern University (United States) offers an integrated science degree through their ISP for superior students.

In the early years of integrated science curriculum development, the act of integrating seems by itself to have led to sufficient improvement in science teaching to warrant the setting up a project. The worth of integration has now been established, and recent programmes are using integrated science as the framework within which to meet the far reaching needs mentioned above.

Another trend has appeared in the initiators. Clusters of individuals in government education agencies and universities have now been joined by others. Science teachers' associations, e.g. Science Teachers' Association of Nigeria (STAN) and the Caribbean Regional Organisation of Associations for Science Education (CROASSE) and science centres such as India's VASCS and Malaysia's Regional Centre for Education in Science and Mathematics (RECSAM), have become initiators and implementers. International agencies such as Unesco, the United Nations Children's Fund, the British Council, the Ford Foundation, the International Bank for Reconstruction and Development (IBRD), the United States Agency for International Development (USAID) and others, through both financial and continuing support, are also playing a major rôle in the spread of integrated science by enabling developing countries to undertake integrated science projects. Perreira's chapter mentions some of the specific ways in which such agencies provide help.

THE LEARNER AND THE LEARNER'S ENVIRONMENT

The setting in which a programme is to be used is unique for each country and it is recognized that curriculum developers must take this uniqueness into account. The important considerations of cultural and natural setting, and political environment, have been dealt with in other chapters (for example, by Pitre and Selim) and we shall confine ourselves here to issues of more general applicability.

Theories of learning are being used more, especially those of Piaget, Gagné, Ausubel, Vygotsky and Galperin, and students are being analysed in their role as learners. The United Kingdom's Science 5/13 classifies its objectives according to Piaget's stages of intellectual development [199, 286, 407]. The projects of the Science Education Center of the University of the Philippines have even employed their own educational psychologists [216]. The Aviology Concept Program (United States), in which flight is taken as the motivator, is experimenting with the use of the Myer-Briggs Type Indicator and Cognitive Style Mapping to understand and design experiences for individual learners [24, 199, 201]. The Trinidad and Tobago Ministry of Education immediately planned a revision of the West Indies Science Curriculum Innovation Project (WISCIP) after an analysis by Mankteloh that found the course to be generally beyond the Piagetian level of the children for whom it was intended [409].

While the complexity of designing an integrated programme demands careful attention to the ways in which children learn, we must recognize that learning theories are still evolving. In addition, there is danger in the application of misunderstood theory in curriculum development and in the classroom, and we have yet to find useful ways of distilling, synthesizing and communicating these theories to the practitioners.

Teacher training is a problem everywhere and is a recurring issue throughout this book. Van der Linde and Cheong have dealt with it in detail, but it is worth recording here a few attempts at solution. WISCIP recognized that teachers would be generally untrained and inexperienced, and made the materials relatively self-supporting with detailed instructions [199, 407, 453]. Chile, faced with the problem of implementing PPS-CN in remote areas, developed an in-service plan for long-distance training so that training would coincide with in-class use of the programme [199, 201, 407]. Several projects have involved teachers from the very beginning, and have provided ways for them to continually reshape the programme as it is taught; other projects encourage teachers to modify the programme for their own locality. Both these strategies are intended to develop investment, commitment and a feeling that they are working with their own programme.

Articulation allowing students to build on prior learnings, both within a course and from one course to the next, is critical but it can lead to sacrifice of flexibility. For mobile or nomadic societies, creative solutions to this problem are needed.

EDUCATIONAL OBJECTIVES

The way in which instructional objectives evolve from the needs which provided the impetus for the programme closely ties them to culture. This leads to a remarkable diversity of objectives. From a survey of over 100 integrated projects, 23 distinctly different kinds of objectives were identified. Table 1 shows an attempt to classify these into five categories.

Table 1 Categories of educational objectives for integrated science teaching

A. SCIENTIFIC LITERACY	B. PERSONAL GROWTH	C. SOCIALLY RELEVANT	D. IMMEDIATE, PERSONAL	E. GENERAL EDUCATION
1. Processes of science	1. View of self a. attitudes toward self b. self evaluation skills c. place in society	1. Comprehension and solution of problems	1. Preparation for exams	
2. Concepts underlying science		2. Practical knowledge	2. Preparation for higher education	
3. Nature of science	2. Intellectual ability a. creativity b. independent thinking c. learning skills d. communication skills e. mathematics skills	3. Attitudes toward school and society	3. Career awareness and preparation	
4. Science and society			4. Survival	
5. Manipulative skills				
6. Attitudes toward science	3. Enrichment of life a. experience base b. life long learning c. excitement in view of the world		1. Effects of man on culture and nature	
7. Values of science				

Notes

- A. FUSE has identified these as the seven dimensions of scientific literacy, a person who is truly 'literate' in science would meet objectives in all seven dimensions. This category covers the objectives most often seen in science programmes. Dimensions 1, 2 and 3 indeed encompass nearly all of the objectives normally found in traditional science courses and in most first generation integrated science programmes. Second and third generation projects tend not only to include more of the dimensions in category A but to extend into categories B, C, D and E, which are not common in disciplinary courses.
- C. These are related to understanding, skills and attitudes that can have immediate social impact. They may, for example, relate to recognizing, understanding and finding solutions to problems in one's environment; developing skills in working with small groups in making decisions, and becoming more positive about one's school and community.
- D. These have value to students in attaining their own immediate goals.
4. This has not been stated as an objective in the programmes surveyed, but it must be considered. Survival depends on learning those skills necessary to live a relatively secure life. In some cultures this may mean learning how to obtain clean water; in others it may include safety precautions in the use of an automobile or electrical appliances. Survival may also refer to the maintenance of mental health.
- E. This is so broad and universal that it could be placed in no other category.

The breadth of objectives found in integrated science programmes may be illustrated by some examples. The Arab League Educational, Cultural and Scientific Organization (ALECSO) project Integrated Science at the Intermediate Schools in the Arab States has scientific literacy objectives: 'development of positive attitudes to science, development of the major concepts of science, and development of suitable skills and processes, both mental and manipulative' [134]. The VASCS Integrated Science project of India lists ten objectives that concern both scientific literacy and personal growth: playing an active role in the learning process, thinking independently, classifying information, knowing facts and concepts about the environment, developing scientific vocabulary, comprehending and applying scientific concepts, communicating effectively, thinking and acting creatively, developing awareness of contributions to science, and problem solving [199]. The project for Science Integration (PSI, Ghana) reports that it seeks to develop

confidence for independent inquiry and action towards positive ends; and to develop faculties and knowledge applicable to situations encountered in the family home, the community, and one's chosen occupation [201].

At the primary and lower secondary levels, the most basic of objectives include developing an ability to survive, an awareness of what is going on in one's environment, and an ability to control one's life and contribute to the improvement of life in one's community. In any country these objectives, applied in appropriate ways, show students that schooling has value for them and are critically important in motivating them towards the more academic objectives of scientific literacy.

Objectives dictated by preparation for higher levels of education or for a national examination often take priority to the needs of the nation as a whole. There is a trend towards examinations more responsive to curriculum, so that the needs of the nation shape the curriculum and examinations; but ministries of education, examination boards and university admissions officers still need to identify better mechanisms for obtaining input from teachers and curriculum developers.

At the tertiary level, it would be appropriate to have a diversity of objectives. The needs of a specialist are different from those of a teacher and, especially at the early level of teacher preparation, scientific literacy objectives would be useful.

The trend in integrated science objectives has been towards the total education of the child (development of socially valuable skills and understandings about one's self) and scientific literacy. There is also a trend towards more and broader objectives, especially the affective ones.

INTEGRATING TECHNIQUES

In a general science course, each discipline is distinct. Integrated science, on the other hand, uses whatever content is needed to attain the objectives, and in this way is more likely to achieve the holistic understanding advocated by Showalter in his chapter. Since an integrated programme could theoretically include all of science, curriculum developers must find designs to facilitate selection and integration of content [216].

There appear to be two general approaches: the *melding* of scientific knowledge based on the underlying concepts and processes of science and the use of integrating themes from life experiences (phenomena and persistent problems) that require an understanding of many areas of science.

Figure 2 may help us to visualize these integrating strands.

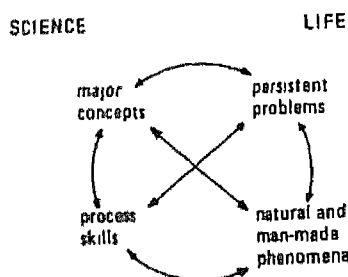


Figure 2. Integrating strands for integrated science

Integration may be achieved by the use of any one of these, but the working group stressed that they should all be used in the construction of a total programme, since all of them tie together in life outside the classroom.

Our study has identified five main techniques for organization and integration. These are shown in Table 2 and exemplified in the notes to the table. It is unlikely that there is any one best integrating technique but the trend appears to be toward a more complete intermeshing of the disciplines into a coherent whole, and an increase in the number of areas of science included.

ORGANIZATION AND CONTENT

The selection and organization of content should be an outgrowth of the project's aims, the nature of the students, the local situation, and the scope of science. Success in reflecting these is more likely with the recent trend of involving, at the early stages of development, teachers, supervisors, parents, students and other components of the education community. Other benefits are that development and inservice training occur hand in hand, and that the resulting programme has a strong foundation of practical experience.

The working group recommended that choice of specific ideas and activities should be based on some consistent model or criteria of pedagogical value. For example, it may be possible to identify a broad conceptual core applicable in many areas (e.g. the occurrence of change) with specific content and reflecting local conditions. Selection of content may be based on age or experience level distinctions such as those described by ten Voorde and Vegting in their papers submitted to the group, or on levels of problem solving suggested by von Aalst, or on some other conceptual framework. Alternatively, selection of content may be made in such a way as to balance, say, academic with real life concerns, or activities intended to stimulate interest with those designed to communicate a body of knowledge. We need much additional work on the question of constructing and synthesizing criteria for selection of content in integrated science.

The selection of content is one dimension of organization. The other two dimensions are determination of the rate of progress and the choice of method or mode of instruction. For each of these dimensions, there are boundaries set by the project, but within the boundaries great variations are possible in the classroom depending on who (curriculum developer, teacher or student) has control. A locus of control is shown in Figure 3. If the student makes choices solely on the

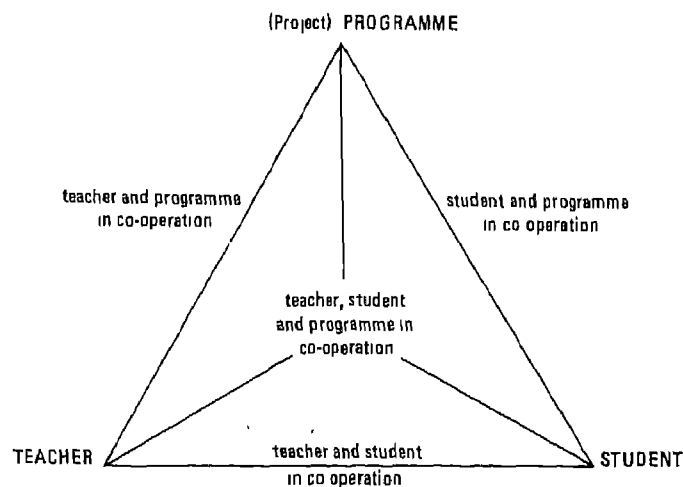


Figure 3. Locus of control diagram for what (content), when (rate), and how (method and mode) science is studied

Table 2. Integrating techniques for integrated science

A. INTEGRATING FOCUS FOR ENTIRE PROGRAMME				
1. Scientific focus	2. Practical focus	3. Personal focus	4. Societal focus	
a. conceptual schemes of science	a. applied (dealing with career choice or local industry)	(dealing with scientific awareness of one's self)	a. historical	
b. processes of scientific investigation	b. environmental		b. technological	
c. nature of science	c. familiar phenomena		c. problems of society	
			d. nature of mankind	
B. UNIT INTEGRATION	C. INTERWEAVING OF SEPARATE CURRICULUM STRANDS	D. INTEGRATING ACTIVITIES	E. SINGLE DISCIPLINE INTEGRATION	
1. Major concepts of science				
2. Scientific processes				
3. Phenomena				
4. Persistent problems				

Notes and examples

A. This tends to be characteristic of programmes organized sequentially.

- Content is organized around academic themes. The Schools Council Integrated Science Project (SCISP, United Kingdom) involves students in the process of searching for patterns and then using the patterns in problem solving [25, 199, 407]
 - The Correlated Science Program (United States) uses a conceptual scheme picturing Change and Equilibrium as two states of nature investigated by scientists using the tools of Quantification, Models and Technology to increase their Awareness of nature and develop Orderliness in understanding [120, 199, 201].
- Such programmes identify key interdisciplinary components of their culture that will have immediate meaning for students. Israel's Agriculture as Environmental Science Project (AES) uses agriculture, commercial and individual, to explore how man manipulates his environment [199, 201, 407].
- This emphasizes relationships between science and society and the social implications of science.
 - Japan's Study on the Integrated Science Curriculum (SISC) considers a series of basic problems faced by Galileo, Newton, Lavoisier and others (e.g. 'how did the phlogiston theory lead to the oxidation theory?') [201]
 - Unified Science and Mathematics for Elementary Schools (USMES, (United States) investigates practical problems taken from the school and local community environment [199, 201, 202, 407].

B. Such programmes consist of flexible sets of non-sequenced units, with an integrating and organizing framework within each unit. Units can be tied together with the various types of integrating strands, e.g.

- concepts: evolution, cycle
- processes: observing, hypothesizing
- phenomena, natural or man-made: forests, flight
- persistent problems: population, food storage [438]

C. The Italian project, Coordinated Science, distinguishes physical science from biological science but interweaves them so that the same basic concepts and certain instructional units are studied in both branches [201, 236]. Foundational Approaches to Science Teaching (FAST, Hawaii) maintains physical and environmental science strands integrated by a third strand called Relational Study and by study blocks of applied science (such as air pollution, world food problems) which terminate each level of the programme [199, 201, 407].

E. Unit Bank Biology (IPN, Federal Republic of Germany) includes themes such as Animal and Machine Locomotion, Balance and Cybernetic Biology [32, 199, 201, 407]. Interdisciplinary Approaches to Chemistry (IAC, United States) hopes to encourage chemistry teachers to become more integrating through self-contained, flexible modules that combine chemistry and at least one other area of science [199, 201, 389, 407].

basis of his or her own felt need and interest, that was to be an essential feature of the programme. Pure teacher control would exist with the teacher making all the decisions, but the student would have a free hand in shaping or building the instruction. The programme was to be designed to be as 'teacher proof' as possible.

For any one project, different levels of control may be exercised by the teacher in the dimensions, content, rate of progress and method of teaching. The programme was to be designed to be as 'teacher proof' as possible.

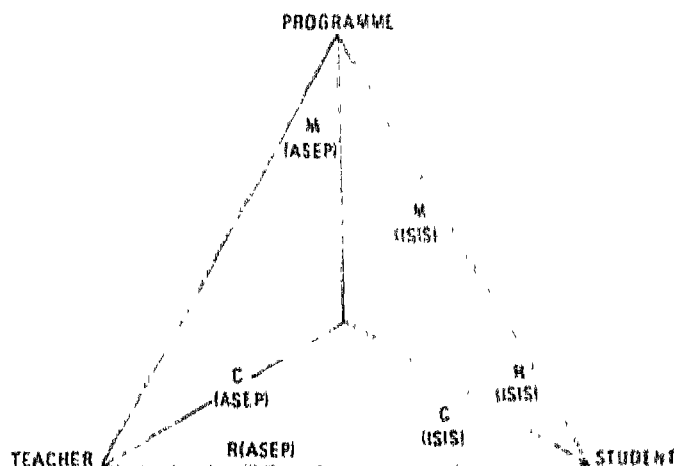


Figure 4 Analysis of Control for ASEP and ISIS
(Control Rate Method of instruction)

approximate locus of control for each dimension of two different projects, the Australian Education Project (ASEP) and the Individualized Science Instructional System (ISIS, United States). ASEP content (C) consists of forty-two units with guides to their selection by teachers according to local needs. The student's rate of progress (P) may vary if the teacher wishes, especially if working on the options. However, all students begin and end the unit together. Method and mode of instruction (M) are predetermined to be student-centred, activity-based, inquiry-oriented. There are no alternative ways of learning the same material, and limited student choice of content (hence mode of learning). Teacher choice is based on programme recommendations concerning Piagetian level [15, 199, 407].

ISIS consists of fifty-five 'minicourse' units. Teachers are given the choice of the degree of student control allowed in the selection of units, ranging from full teacher control to complete student control. Within each unit there is a high degree of student choice based on self-paced assessment and interest. Rate of progress is restricted only by activities required by the programme. The method and mode of instruction are partly under student control in that the student chooses the activities he or she will do, and there is great variety among the activities. However, the programme does not offer alternative modes for learning the same content, and it specifies individual or small group activities with teacher management and advice [161, 201].

Integrated science programmes range from *sequential* to *non-sequential* in arrangement of units. In sequential programmes each unit builds on learning of prior units toward long-range goals set in order based on a conceptual scheme or theory of learning. Science - a Process Approach (SAPA, United States) is structured to provide a developmental progression of increasing competence and

the other extreme of science [149]. At the other extreme are non-sequenced courses which provide great flexibility by consisting of totally self-contained segments. The Curriculum Resource Bank at the RMC (1977, 1981a) consists of a file of key-sort cards containing curriculum ideas for use, many contributed by participating teachers. Programmes of this kind can be shaped to fit local conditions, individual teachers or even individual students [199].

That projects lie between these two extremes, the tendency being to suggest sequences while allowing for further selection of units or modification of their order. Japan's Basic Science Curriculum Materials for eight major topics (e.g. light, energy, evolution) which can be freely arranged by the teacher into complete or partial programmes having a variety of themes [168].

Various degrees of sequencing are also found in the activities that make up units. In the FUSE programme model all students follow the same unit at the same time but they have a degree of choice in the order within the unit. In other programmes, there is flexibility in selection of the unit, but once a unit is selected all the activities in it must be completed.

Two major trends are apparent. The first, exemplified by Scotland's S1 and S2 [201], is a compromise between prescribed sequence and individual choice. In each unit there is a prescribed sequence for essential work and enrichment, but the teacher determines which units will be taught. The second trend is toward much greater student choice.

The extent to which students progress also varies in degree of control. Most commonly, students are kept together in class with only slight variations. Some curricula have the class together at the beginning and end of a unit only. This allows for individualization within the unit and, at the same time, large and medium sized group teaching strategies. Interrelated Explorations in Science (1980, 1981a) uses a day-to-day individualization technique in which all students begin the day with the same activity, but faster students may do additional activities that amplify the same concept [128, 199, 201]. At the extreme are fully self-paced programmes giving great flexibility and individualization, but these significantly reduce opportunities of group interaction. Several projects, such as Ecological and Environmental Education (Federal Republic of Germany) are designed for self-pacing by small groups rather than by individuals.

The range is wide from didactic exposition (teacher-centred) to open-ended inquiry and discovery (student-centred). While there are numerous examples of the former, there appears to be a strong trend toward the latter. The Lesotho Introductory Science Improvement Programme's (LISIP) underlying principle, 'learn by living', extends throughout the classroom [199]. Modes of instruction in programmes include lectures, discussions, readings, experiments, field trips, projects, multi-sensory approaches and others. Some programmes rely heavily on lecture but most make extensive use of laboratory work. Many use a wide variety of instructional modes as a strategy to motivate and to meet the needs of individual learners. Others emphasize only one or two essential survival teaching-learning modes. In the Samoan Sea Study Lab programme (SSSL), students spend a significant proportion of their time on boat trips, in a floating laboratory, at an offshore marine laboratory or on coastal field trips in an attempt to overcome general apathy toward ocean resources.

The trend seems to be toward compromise between structure and teacher choice, and this is exemplified by a required core augmented by enrichment and skill-building activities as needed. There is also a trend toward increasing student choice of topics. In all three of the dimensions discussed, developers are tending to build in flexibility for local choice and thus more potential for relevance. Also on the increase are inquiry approaches, educational technology and variety in instructional modes. To physics, chemistry and biology are being added more sciences such as geology, astronomy and psychology, all being woven together to facilitate understanding of concepts, processes and topics of an interdisciplinary nature.

SUMMARY

Just as there has been a trend toward a rapid increase in the number of integrated science

programmes existing world-wide, there have also been very distinct positive trends in the changing character of these programmes. In general, the trends seem to indicate a greater focus on the importance of the learner and a greater understanding of the nature of science as an integrated whole. Trends are seen toward increasing relevance, greater attention to the needs of special groups of students, more and broader objectives (especially affective ones), tying science more closely to society, more complete and creative integration, and increased flexibility in programme design. One especially important trend is the greater attention paid to research and theory on how children learn.

Because integrated science is aimed toward general education and extends even beyond science, the aims are tending to focus more on the child than on the subject of science. Thus, learning theory is becoming an integral and essential part of integrated science teaching and curriculum development. This trend may be especially well suited to integrated science since it offers the opportunity for inquiry of a wider scope, more relationship to life, and broader generalization than a disciplinary approach.

Along with these trends comes greatly increased teacher responsibility. In many cases, the teacher needs to be conversant in integrated science, assessment of student progress, and prescription of activities, curriculum design and modification, and learning theory. This implies a need for pre-service and in-service teacher education, which we recommend go hand-in-hand (wherever possible) with the curriculum development. It also implies a need for special training for curriculum developers.

However exciting trends may be, it is essential that we remember that each curriculum development project must be designed with respect to the needs, opportunities, and constraints of the people and place where it will be used. Thus the working group recommends that every effort be made to involve people from all elements of the education system in the development of objectives - especially teachers.

A great diversity of programmes have been developed which can be used as models and stepping-stones to the next generation of improvements in integrated science. We must find continuing ways to share the wealth contained in these projects and find structures that will facilitate our study of them.

The International Council of Associations for Science Education (ICASE), and others, have taken very positive steps in the direction of sharing the experiences and materials of existing programmes with those newly beginning. These efforts must be continued and expanded with the help of science teaching organizations as even more countries move toward an integrated approach to teaching science.

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See also [122, 269, 270, 271].

7. Resources for the introduction of integrated science

Rafael Ferreyra

There are now many countries which have succeeded in developing and in introducing integrated science courses, so that a substantial amount of instructional materials, information and know-how is potentially available. For school systems which do not yet have integrated science teaching established, this chapter attempts to identify resources which would be helpful in the introduction. Many of the resources exist already, but the working group found that there is need for the development of some new resources. It is assumed that there is in a system someone who thinks that an integrated science curriculum is an appropriate solution to observed science teaching problems and who has appropriate leadership qualities, position, background and skills. (Of course, he is himself an essential resource.)

DEVELOPMENT OF INITIAL IDEAS

Among the many existing resources are the New Trends in Integrated Science Teaching series, the International Clearinghouse Reports which are excellent collections of information about projects, and many of the publications listed in the general bibliography to this book. Science teaching centres in various parts of the world have collections of curricula, or information about them, and can provide guidance on starting a project. Unfortunately, access to these resources is not always easy. There could be a language barrier; visits to the centres may not be easy, and the printed resources are not well distributed within countries.

The following new resources are suggested.

1. Reference index. This would list existing integrated science curricula, providing a profile that would be useful for initial decisions. It would be simple and quick to use. (This may well be the same idea as that proposed by Frey in his chapter.)
2. 'What is integrated science?' This is seen as a book which would facilitate understanding the concept of integrated science and its aims and methods, and it would have practical examples of good materials and classroom teaching. Again, it would be simple to read, handy, and cheap enough for the classroom teacher (the importance of this will appear later). For this book there is special need for wide diffusion and good publicity, which implies translation into several languages and availability through commercial channels.
3. Communication network. This is intended to facilitate exchange about integrated science at international, regional and national levels, and Frey has proposed something similar. Although most of the components of a suitable network exist, there are missing links which should be identified, and the gaps should be filled.

Meanwhile, it would be useful to carry out studies on how resources reach the users and on how their accessibility might be improved.

PROPOSING THE IDEA TO THE DECISION MAKERS

Once the initial idea is clear, it has to be taken to the Ministry of Education, university, funding agency or some other institution in the form of a project proposal. If it is to be taken seriously, the proposal should attend to the following matters, amongst others. policies of the decision makers; basic objectives and outline of final product (original curriculum, adaptation or adoption); human and financial demands and resources (including estimation of staff, time and money); aspirations of the clients (teachers, administrators, students, parents and decision makers), economic feasibility (a realistic estimate of cost per student); institutional feasibility (including the preparation of teachers and the support from schools); and political viability, which refers to the values of the power system (important problems, population for instance, are appropriate for integrated science but may not be appropriate in a particular country, the adaptation or adoption of foreign materials might not be compatible with national attitudes). Many interesting projects fail because the resource requirements for either the development stage or the implementation stage are underestimated, so the project proposal has implications beyond that of selling the idea.

Literature on project proposal preparation exists as far as productive projects go, but for educational projects it is scarce. Those preparing a project proposal would find the following resources valuable.

4. Guidelines for the design of integrated science projects. Since needs differ, there would be a variety of models.
5. Handbook for the development of integrated science curricula. For the initial stage, this would be useful for preparing an outline of the product for the information of the decision maker. For the development stage, most decisions could be helped by examples of methodologies and other information. An example of the sort of handbook in mind is the *Do it Yourself Curriculum Guide* produced by the Department of Education of South Australia [84], although the particular example is not applicable in all countries; it makes use of curricular materials which could demand resources not always available to the teacher.
6. Curriculum implementation guide. This would help the decision maker at both the project planning and implementation stages by outlining the implications of a development in terms of initial capital outlay, annual running costs, teacher training programmes and so forth.

PREPARATION FOR DEVELOPMENT

For the sake of simplicity, we now assume that the proposal has met the approval of the decision makers and that initial resources have been allocated to the project. The next operation is the organization of a team and facilities for the development of the course. The logistic activities are various and include the selection of personnel and the gathering of other resources. So we seem to need

7. A collection of reference materials for the development planning stage. These would be based on successful cases.

THE DEVELOPMENT PROCESS

Once the project is ready to start, the development process consists of several stages. The first stage is the design of the preliminary version. Learning objectives and evaluation procedures are specified, student activities are designed, media are selected, texts are written, apparatus is selected (or adapted or designed), and quantities of materials are then reproduced for school trials.

The second stage is the trial in which trial schools are selected, teachers and observers are trained, authorizations are obtained; then the materials are used under real school conditions and information is gathered. The third stage is the revision stage when materials are modified using the feedback from the trials and tried out again and again until the desired result is obtained. Hopefully, in a parallel process, teacher training materials are developed, tried and revised. In the fourth stage, information obtained in the first three stages is put together in order to facilitate the next decision. If the system is a centralized one, the next decision-maker might be an educational authority; alternately, he might be a commercial publisher. In either case, his expectations and information needs have been explored before starting the development and have been taken into account in the design of the evaluation procedures.

Useful resources for these various tasks are publications on educational technology [364]. However, some further resources for the development of integrated science curricula are indicated.

5. The development Handbook mentioned above.
8. An equipment index. This would concentrate on improvized and low-cost equipment, giving essential construction details (photographs, dimensional drawings, constructional materials and operational limitations). There would be attention to prototypes and the production of semi-industrial and industrial versions, bearing in mind the availability of materials, although in most cases mass-production would not be feasible. The University of Maryland guidebooks [398] are very useful, but something more extensive is visualized. If the details were in sheet form, they could be mailed quickly to where they are needed, avoiding some of the availability problems found with large manuals. It would be useful if Unesco could add this service to its other activities promoting the local production of low cost science equipment.
9. Independent assessments of commercial apparatus. With these, decision-making about the construction and/or purchase of equipment would be quicker and more effective. The National Science Teachers Association, NSTA (United States) science material and apparatus review committee has produced information that seems adequate, and it should be disseminated more widely.
10. Guides for using the local environment and community resources. An interesting example is the Yellow Pages on Learning Resources from MIT [391]; another series comes from the National Council of Educational Research and Training (NCERT) in India [413]. The latter refers to primary science experiments using local resources. The guides would be addressed to teachers, detailing procedures for preparing an inventory of local resources, organizing a scrap collection, and using student and community help to produce their own materials. At the development stage, the guides would be used by curriculum designers when preparing their materials, including teachers' guides.

IMPLEMENTATION

Other chapters in this book deal with dissemination and implementation in a number of particular contexts. To identify some of the resources needed, it might help if we consider an example of a set of decisions.

The educational authorities of a centralized system have decided that the programme should be implemented next year in all schools, and that the materials will be mass-produced locally. The printed materials are to be purchased and distributed by the Central Office, and the equipment and supplies will be ordered by the individual school districts.

Although the case, on the surface, does not look very complex, many different operations have to be carefully programmed; responsible agents must be identified and instructed; and the corresponding resources must be produced at the right time. Detailed specifications for book publishers must be prepared, a printed material distribution system organized, specifications for manufacturers prepared. Procedures must be developed for the purchase, delivery, reception and servicing of equipment. A massive teacher training programme must be developed and implemented. Special material

must be developed for administrators, supervisors and others, and the operations must be monitored. Not such a simple operation after all!

Implementation is basically a problem of organizing and programming a complex set of operations which involve a variety of people - it is a basic principle that each person should know his rôle precisely. Implementation has not worked very well in the past, and it is suggested here that a prime cause has been the failure to recognize the logistic planning required.

The working group identified some resources that would be useful.

6. Curriculum implementation guide mentioned above. If this included the many alternatives that appear in different countries, it would be very useful for programming the implementation. It would, however, be too general, too complex and too bulky for use by those responsible for specific operations.
11. Specific guidelines for individual operations. This would be produced locally, using the implementation guide as a source book.

RESOURCES NEEDED FOR THE INTRODUCTION OF INTEGRATED SCIENCE WHEN THE TEACHER PLAYS THE MAJOR ROLE

This chapter has so far assumed that development and implementation will be carried out to the final stage by the specialized sections of the educational system. The teacher's rôle is to teach. Perhaps a few teachers have participated as members of the curriculum team, or in trials, but the responsibility for retraining and for providing the resources was assumed by the system.

There is a different educational situation where the system initiates the process but then adopts a passive rôle, assuming that the teachers will carry out most of the operations. This pattern is typical in countries in which the level of resources allocated to curricular innovation is low. We shall illustrate what might happen.

Case 1. The educational authorities in a particular country decide to replace separate science disciplines in secondary education by integrated science. A technical commission is appointed to develop a new national syllabus. Each person in the group is selected for his knowledge and experience in teaching a scientific discipline. Each member of the commission selects portions from his own subject, and all are pasted together in sequence. The resulting syllabus is then approved and becomes mandatory for all schools without further testing or discussion. Teachers feel uncomfortable with such a mixture of topics, basically because of their training in one discipline. They have new responsibilities, but no specific materials have been provided for them. Book publishers quickly rearrange old material in hand and put out new books to satisfy the emerging demand. The Ministry of Education then promises to organize training courses for teachers.

Case 2. In another country the same initial decision is made, and the Curriculum Division of the Ministry of Education undertakes to develop a new integrated science syllabus. The division gathers relevant technical information and designs a sequence of objectives, activities, experiments, evaluation instruments and so on. The design would be recognized by any of us as a modern approach to integrated science. It is, however, neither tried out nor discussed with teachers, and becomes the official syllabus. It is further decided that a pre-service programme for integrated science teachers will start immediately. The teacher trainers at the Central Pedagogic Institute lack methodological guidelines to deal with integrated science properly, and have no access to the wealth of potential resources mentioned above.

These cases illustrate the consequences of lack of understanding of the importance and availability of resources. Excellent opportunities are lost. The development team has stopped at the production of a syllabus, and from that point the textbook authors and teachers are left to identify and perform the remaining operations. If the syllabus is without objectives, suggested activities and materials, the situation is even more *ad hoc*.

In such circumstances, the most important resource is a resourceful teacher who can identify, gather, organize and utilize the learning resources needed by his students. Such skill is especially valuable when the educational system provides poor financial and technical support.

There already exist pre-service and in-service teacher training programmes for integrated science teachers, and their number will undoubtedly increase. In this book the contributions of van der Cingel and Cheong are relevant.

Further resources for which a need exists are the following.

2. 'What is integrated science?', mentioned above.
10. Guides to local environment and community resources, also mentioned above. Both these resources would have to be designed with this kind of user in mind.
12. Manual for the training of integrated science teachers. This would be for use in the design and implementation of training programmes, and would be addressed to planners in Ministries of Education, universities and teacher training colleges. It would include a consideration of traditional training in various types of institution, and methods of designing and implementing massive training programmes utilizing the mass media.
13. Self-training materials. The need for these is especially great for teachers who work in rural areas with little access to the communication networks, so their design and distribution deserve special consideration.
14. Local groups of teachers. Such groups can co-operate fruitfully in the development and production of learning resources for integrated science. Each group needs a person with leadership if it is to survive for more than a few meetings, and it should have a definite project on its hands. A group would be part of a network of human resources which deserves promotion at the national level as a resource for curriculum development and teacher training. A science teachers' association may grow from the network, or use it for professional upgrading of its members. The groups need a course or curriculum to help them help themselves, to provide structure and direction for the group activities. An example of a curriculum associated with such a network is the PPS (Programa de Perfeccionamiento en Servicio) produced a few years ago by the Ministry of Education in Chile.

LABORATORY EQUIPMENT

Most equipment problems can be seen as blockages to the smooth flow of utilization of resources.

THE CASE WHERE THE EDUCATIONAL SYSTEM DECIDES TO PROVIDE EQUIPMENT TO SCHOOLS

Equipment may be purchased from abroad or within the country; it may be requested from international aid agencies like Unicef; standard or low cost equipment may be manufactured within the country; or teachers may be given resources for improvisation. At the initial decision, problems may arise when the decision makers are not fully aware of the alternatives and their implications, and have no data on which to base the decision. Sometimes only commercial catalogues are available.

The resources actually needed will depend on the problems and blockages, which might be identified from the following sequence of operations: ordering (determination of adequate quality and of associated equipment, spare parts, and a reliable supplier); transit (damages, losses, delays in Customs); inspection and storage (lack of adequate instruments and specifications, space, care); distribution (essential parts of a single kit may be sent to separate schools, distribution may be divorced from teacher training); transportation, reception and temporary storage (equipment may be damaged by clumsy handling and lack of space); setting up and utilization (lack of appropriate instructions in the local language, lack of training for teachers, lack of technical help and storage space, government policy obliging teachers to pay for accidental breakages); and maintenance and repairs (lack of expert technical assistance or specific training for teachers, lack of replacement parts, tools, facilities and funds that can be drawn on for this purpose).

Aid agencies like Unicef and IBRD are aware of these problems and have laid down requirements for a client nation before any materials or equipment are delivered, but even with these safeguards things can go wrong.

School systems can rarely compete in salaries with industry, and formal training opportunities are offered in few places, so that even if the school system does make provision for laboratory assistance, the personnel is often untrained. Laboratory management skills are essential for the smooth operation of laboratories, so that there is urgent need for training for assistants and for science teachers.

Some excellent resource materials exist. Some have been mentioned already, and others are Warren's book published by Unicef [448] and the book produced by NCERT (India) on the training of assistants [412]. Some further resources are needed in addition to the implementation guide and others mentioned earlier.

15. An auto-instructional book for laboratory assistants.
16. A manual for the organization of mobile service units. This idea arose from mention of the very interesting mobile maintenance and repair service of Lagos (Nigeria) that periodically goes to schools to take care of those operations which are beyond the school's resources.

THE CASE WHERE THE TEACHERS HAVE TO DESIGN AND IMPLEMENT, MOSTLY BY THEMSELVES

When the starting point for the teacher is just a syllabus as a list of topics, he has to do a great deal of planning and make many decisions. The *New Unesco Source Book* [198] is one resource that is widely available. Some further resources would be useful.

5. The development Handbook mentioned earlier. This would provide specific guidance on the development of software for integrated science curricula, but only some sections would be needed by the teachers of a particular country; someone would have to extract those sections for distribution to teachers.
17. Teaching guide for integrated science. This would include some educational theory designed to help the teacher understand the need for children to learn by interacting with their environment, manipulating apparatus, and also by discovering the meaning by mental operations. (In general, the physical manipulations have been over-emphasized in the past and the associated mental operations have not received much attention.) If the teacher has to improvise apparatus, he cannot usually produce enough for class sets. But even if the manipulations are performed by only one or two students or the teacher, the whole class can participate in the experiment in its mental aspects. Collective experiments are far better than no experiments at all. For several years to come, many teachers will be able to choose from no other alternatives. The guide would help them to make the situations meaningful. It might be structured according to the processes of science, and it would demand only simple improvised equipment. Teachers learn from teaching, inter-acting with students and often arriving at meanings for themselves. Each lesson could be a truly scientific experiment for the teacher. If the guide could use this idea as a basis, helping the teacher to perceive those meanings, he will become independent of guides for the teaching of integrated science.
18. Single topic books. These are seen as a complement to the guide just mentioned, enrichment readings for teachers and students.

COMMUNICATION NETWORK

This has been mentioned earlier, but as a resource it is so important that it merits emphasis in the whole context of the introduction of integrated science teaching. The network facilitates the flow of ideas and resources at international, regional and national levels. Groups of teachers are crucial components of this network, and the individual teacher is another crucial component. He receives the information filtered by the different hierarchical levels, and eventually is trained according to the perceived needs of the system. He is more than a passive recipient,

however. Every day he has opportunities to exchange ideas and to co-operate with the colleagues in his school. If he is a member of a science teachers' association he associates with other members of his profession on the basis of common interests and concern for professional excellence. Where science teachers' associations (STAs) exist, they usually work in close co-operation with the educational authorities (although there are some governments which do not permit such associations).

Experience has shown the value of STAs as resources in the introduction and promotion of innovations. In Nigeria, for example, STAN assumed responsibility for the development of an integrated science curriculum. A similar case has occurred in Mexico. The most recent example is the Nijmegen Conference, for which the Netherlands STA undertook major responsibility, and which will probably influence the diffusion of integrated science education in the Netherlands. In many countries STAs are publishing professional journals, promoting and organizing courses and seminars, developing teaching guidelines, and carrying out many other important communication activities. ICASE and its affiliated STAs are promoting the formation and assisting in the progress of associations.

There remains the problem of a large silent body of teachers who either are not active in the associations or do not join them at all.

THE ROLE OF INTERNATIONAL CO-OPERATION AGENCIES

The most obvious role of international co-operation is the promotion of exchange of ideas and information, normally achieved through publications, seminars, conferences, fellowships and so on. The work of Unesco in this respect is well known; just a few examples are the New Trends series, the Source books, and the sponsorship of several conferences on integrated science. Other United Nations agencies, the Food and Agriculture Organization (FAO) and the World Health Organization (WHO), have sponsored alone or in co-operation with Unesco the preparation of manuals for teaching nutrition and health, and are promoting the development of human resources in those areas.

Unicef has been co-operating with educators in a number of ways. It has provided science teaching equipment and other learning resources to schools and teacher training institutions. This kind of material is listed in two useful publications [446, 447]. Warren's book [448], though designed for users of Unicef equipment, contains valuable suggestions for more general use. Unicef (with the United Nations Development Programme, UNDP) is also sponsoring integrated rural development programmes which have important integrated science implications. Another Unicef sponsorship is a Regional Interagency project in Latin America for the promotion of food and nutrition policies; it is developing integrated science materials for decision makers and planners and is expected to have an impact on educational programmes.

Other special funds of the United Nations are sponsoring programmes in population education, environmental sciences and so on, which in fact are integrated science.

The Commonwealth Secretariat has also made important contributions, sponsoring conferences and publications on school science equipment. One of their publications, by Warren and Lowe [449], is a well-known example.

CONCLUSION

All the resources needed for the promotion and improvement of integrated science, as identified in this chapter, require international co-operation for their development. The basic aim of this chapter was precisely to identify those kinds of resources which, derived from other resources internationally available, could help individual countries, and individual teachers in those countries, in the introduction and improvement of integrated science in their schools.

Editorial Note: Some of the needs identified in this chapter may have been met by the contribution of Dr. Gadsden and co-workers, given as Appendix I to this book.

8. Towards the implementation of science at the primary level

Wynne Harlen

This chapter looks at the strategies which have been used for implementing science in the primary school and tries to identify the strengths and weaknesses of each. Dissemination and implementation strategies must, of course, be suited to the nature of the curriculum material which is available as well as to the educational system. However, the focus of attention here is on the process by which teachers come to introduce science materials or ideas into their work, rather than on the development of those ideas themselves, as the latter has been dealt with in the paper by Gadsden *et al.* This is not to say that in practice these two subjects can really be treated separately, for one of the major lessons that has been learned about dissemination activity is that if one begins to think about it only when materials have been prepared, then it is almost bound to be doomed to failure.

THE NATURE AND SPECIAL PROBLEMS OF SCIENCE AT THE PRIMARY LEVEL

Despite all the efforts of the past fifteen years, it remains the case that where teachers have any choice in the matter, little science is taught in primary schools, and where there is no choice, what is taught in the name of science bears at times tenuous resemblance to scientific activity. Handling materials, though it gives the opportunity for scientific activity, does not lead automatically to it. The children may be so closely directed that they have to follow a recipe - they *do*, but do not *think*. Alternatively, science may be presented, through 'chalk and talk', as principles and facts to be learned, so that children have to commit to memory the ideas which they should construct themselves.

Teachers vary in their background and experience in relation to the knowledge, skills and attitudes involved; and the opportunity for each to progress to the point where he can apply these in the classroom is to be found in discussion and practice during pre- or in-service courses rather than in teaching materials or teachers' guides. Both informal observation [430] and formal investigation support this point. Information of this kind came from part of the Science 5/13 (United Kingdom) evaluation. When teachers were using the materials on a trial basis, they completed, both at the beginning and end of the six month period, a 'preference' form which was a measure of attitude to the child-centred inquiry approach of the project. There was a high correlation between initial score of the 'preferences' and a measure of implementation of the project's approach derived from classroom observation, but little change of score from beginning to end of using the material. From the latter finding, it was concluded that use of materials *per se* produced no change in teachers' attitudes to the methods embodied in the materials, and from the former that it was necessary to establish favourable attitudes before materials could be used effectively [141]. In response the project produced *Understanding Science 5/13*, a publication based on the problems of initiating science activities and on the worries which teachers themselves expressed [443].

The central issue in the discussion of the nature of primary science concerns the balance of emphasis on content, the facts and principles which help in understanding the environment, and the skills and attitudes which constitute the processes through which the content is learned. There is wide agreement that both content and process are important, but less consensus on the questions of the relative emphasis in one or the other and on the extent to which either should be prescribed. Whilst process goals are frequently stated explicitly, project materials vary widely in relation to content goals [146]. The issue may be clarified by a more careful examination of what we mean by content. A useful distinction can be made between *concepts* or *generalizations* which relate to a number of different objects or situations (for example, the idea of adaptation of living things) and the particular *contexts* in which these are applied (in the adaptive features of particular plants or animals). The *contexts* are of immediate concern to the children; these are the problems they work on, the investigations they pursue, where they gain the satisfaction of achieving understanding. Activities in various contexts contribute to gradual growth of *concepts* and broader ideas which are used when problems in new contexts are encountered. Thus there is a continuous development of concepts, derived from specific activities in specific contexts, being used in, and modified by, further experiences.

In the face of current pressures on teachers to concentrate on 'the basics', implementation of science programmes will depend quite largely on whether they are convinced of the values to their pupils of time spent in science. It is not the place here to spell out these values, but it is relevant to indicate that they should be stated clearly and in a way which links science to the work already going on in the schools. New activities or projects generally have to be justified to a far greater extent than ones already existing in the curriculum. Innovators, too, have often been the scapegoat for existing inadequacy, as when the falling standards in schools are blamed on the introduction of new work in a handful of trial schools. Science has a great deal to contribute in terms of the basic skills of literacy and numeracy, but curriculum innovation is often carried out in such a way as to put science into competition with other subjects. Greater co-operation among curriculum development teams dealing with the different subjects is needed to provide a more unified approach to innovation in the curriculum as a whole, and so prevent teachers from being torn between competing demands on time.

A further problem arises in relation to the values and attitudes which primary science programmes either explicitly or implicitly aim to develop in children. Thier's [317] review of primary science programmes shows that, although there are considerable differences among them in several respects, they all agree on the importance of direct experience and on the teacher's rôle as supporter of inquiry rather than solely a source of information. This may, however, be asking the teacher to adopt a different rôle from that accepted in the rest of his work and different from that which is the culturally accepted relationship between adult and child. Teaching science involves a variety of methods and approaches, some of which are familiar to the traditional teacher; but to pursue the goals of many recent programmes, the teacher has to be willing and able to encourage children to raise questions and to take initiative. Implementation would also require a teacher to establish such a relationship with the pupils that they feel able to express their ideas without fear of giving the 'wrong answer', for only then will the teacher have knowledge about the foundation on which further ideas are to be built.

An important factor which impedes implementation of primary science relates to the background knowledge of the teacher. Whilst there is no doubt that this is a very real problem, requiring constant attention from in-service and pre-service teacher educators, it is perhaps made to appear more serious than it is through misunderstanding of the nature of primary science. When the task is seen as one of passing on scientific principles and information then most primary teachers regard their own knowledge as inadequate. When science is inquiry-based and child-focused, however, the amount of factual information required by teachers is often no more than they, as intelligent adults, have already acquired. Teachers in fact have much more knowledge that is relevant to teaching science, as interpreted here, than they think they have. A teacher in the SEPA project was observed during a lesson concerning soil. The children were asked what kinds of different soil they knew of; they replied in terms of usage of soil, that is, there is soil used for building, soil used for roadmaking, soil used for growing things. This was not the 'scientific' one, based on the composition of different soils, but it was not rejected by the teacher to be replaced by the 'right' answer, as might have happened had she regarded her rôle as being to pass

on information. Her everyday knowledge was adequate to help the children investigate and classify soil in their own terms.

It must be acknowledged, of course, that everyday knowledge will not always be enough and a teacher needs to have access to information and to be able to develop her own understanding. Where possible there should be a teacher in the school with special responsibility for science who can act as adviser and resource to other teachers. But the science teaching is best left in the hands of the classroom teacher, not organized so that it is taught by a specialist. In this way, the children's scientific development will be encouraged in a range of activities, in subject matter across the curriculum and in the hands of the teacher who has a thorough knowledge of the pupils.

Experience has shown that there is much to be gained from starting with the problems, such as have been outlined, which are perceived by the primary teachers themselves, rather than dealing with these problems as though they were unfortunate obstacles to the implementation of a programme and a set of goals conceived elsewhere. It would, of course, be inaccurate as well as unfair to ignore the participation of teachers in the development of all programmes, but a close examination of the rôle they are given often reveals that this is restricted to development within a framework which has established the area of activity and the goals of the work; rarely are they free to define those problems and goals [144].

IMPLEMENTATION AND RELATED CONCEPTS

A variety of terms is used in discussing the process of bringing about change in children's learning experience. Though teachers themselves are on occasion the initiators of change in their own classrooms, for the vast majority the situation is that innovations are conceived outside the classroom and have somehow to be brought inside. Words used to describe this process include 'dissemination', 'adoption', 'implementation', 'diffusion', and 'innovation', and it is necessary to clarify their meaning and relationship in order to identify what they involve and when they occur.

What is suggested here to clarify the terms used follows the lines mapped out by Kelly [178], by Rudduck and Kelly [438], and discussed in relation to physics teaching by Reay [425]. Dissemination is seen as having three phases of which implementation, meaning putting a change into practice, is the last. Firstly, there is *receptivity*, or preparing persons or institutions for change; if successful, this preparation leads to *adoption*, or a commitment to change, thirdly, the intention to change may be put into practice, which is *implementation*. It is clear from this breakdown of the dissemination process that it is incomplete if it consists only of spreading information about the change, that is, stopping at the receptivity stage. It is also incomplete if it stops at the adoption stage, where there is knowledge of the change, agreement that it is worthwhile but yet nothing results in practice from these two stages. Another term used in this context is *diffusion*. It generally implies a less deliberate spread of information than dissemination. Diffusion uses the existing networks for communication which vary from one situation to another; it is more commonly found to operate in decentralized systems.

As well as suggesting the three phases of dissemination, Rudduck and Kelly also proposed four components of the process: translocation, which refers to the movement of materials or persons necessary for implementation; communication, meaning the passage of information from one person to another, by written material, other media or personal contact, and is a two-way process; animation, which means providing a stimulus for change through external incentives or intrinsic motivation; and re-education, referring to the development of understanding and commitment needed for effective implementation.

These are interdependent in a hierarchical way, communication depending on translocation, and re-education on the presence of the other three components.

Experience has shown that there is need for re-education if changes are to be lasting and thoroughly integrated into the work of teachers; dissemination strategies which have not included this component have resulted in pseudo-implementation, a change in surface features only, a change which is all too readily reversed when the excitement and attention surrounding an innovation is removed. Early strategies tended to concentrate on translocation, distributing materials, and on communication, mainly through the written word. It was soon realized that this did not produce even 'animation' to any extent and was a long way from 're-education'; it brought the horse to the water but ... But animation and re-education depend upon communication and translocation, thus a strategy which has any chance of success must include all four. Examining strategies in terms of the attention given to all four components is thus a useful way to begin evaluating them.

It is also useful to refer to the models of the diffusion process which have been described by Schon [431]. These are models describing mechanisms for inducing change in social systems in general rather than in education in particular, but they have considerable relevance to curriculum dissemination. In the first of his models, called the 'centre-periphery' model, Schon describes a process of communication and movement of ideas and materials from the centre where the innovation has been created to the persons and places, at the periphery, where it is to be used. The 'centre' might be a curriculum development centre, where teams work to produce new materials and then distribute them through courses, or school suppliers, directly to the schools.

The second of Schon's models is one which retains the notion in the first of a message passing from a centre outwards, but includes a number of secondary centres set up and supported by the primary centre. For this reason the model is described as one of 'proliferation of centres'. The rôle of the team at the primary centre is one of training leaders of the secondary centres so that the effect is to multiply many times the manpower at the centre. Often this also relieves the centre of some financial burden since the secondary centres may be supported locally. The early Nuffield projects in primary mathematics and science for example, were instrumental in setting up Teachers Centres in the United Kingdom, financed from local authority funds. When these were in operation, the project teams could change from giving courses directly to teachers - a centre-periphery model - to giving courses to local leaders who could use the centres for running their own courses for teachers.

The third model for diffusion identified by Schon is that of 'shifting centres'. In this there is no primary centre which initiates the materials and ideas, but instead centres are created to respond to problems perceived by a particular group. A centre may exist as such for as long as required to address a problem; thereafter activity may shift to another centre. In the curriculum development field, one may perhaps interpret this model not as indicating shifting locations of innovation, but shifting foci of innovation, the work being undertaken in response to problems identified in the field rather than at some centre.

These models may help to provide a theoretical framework for examining dissemination strategies and possibly lead to the identification of weaknesses in these strategies. This presupposes, however, some way of judging the relative success or failure of attempts at dissemination. Since Bajah in his chapter of this book deals with evaluation, the subject is not being dealt with in any detail here, but it is appropriate to draw attention to some special difficulties in evaluating implementation. The target of dissemination is the teacher, and the effect on the teacher will depend not only on the strategy employed but also on the training, experience and attitude of the teacher. The effect of any change in the teacher will first be seen in the opportunities provided for the pupils; then how these influence the pupils' learning will depend not only on the opportunities but on many other factors relating to their background, the teaching methods to which they are accustomed, and their out-of-school experience. Thus although the purpose of dissemination is to affect children's learning, there are so many confounding variables that pupil achievement measures are not likely to provide a valid measure of implementation. Instead an evaluation must begin by examining the situation in which change is attempted and should use methods to explore effects upon teachers and pupils which take account of the multiplicity of associated factors and related variables. Evaluation should also acknowledge that no innovation can be implemented in one classroom exactly as it is in another, neither is it always appropriate

to attempt to implement certain ideas or materials without considerable adaptation to suit the context and constraints. Thus we have the paradox that in some cases it may be better for the pupils' education if what is implemented is somewhat different from the innovation that is being disseminated than if dissemination were more 'successful'. Such problems as this bedevil any attempt to measure the effect of a particular dissemination strategy; the following section provides a description of what can be done by particular strategies, leaving others to decide on the success of one or another.

FOUR STRATEGIES FOR DISSEMINATION

For the purpose of discussing the advantages and disadvantages of various approaches to dissemination, it is proposed to look at four which are distinctively different. However, it would be best to regard them as points in a continuum of strategies, rather than as representing the only possibilities. In the order in which they are described here, they progress from those giving most attention to introducing particular teaching materials to those giving most attention to teacher preparation. Examples are given of projects in various countries which exemplify a strategy but this does not necessarily mean that only one strategy is used by a project; most, in fact, employ several.

Strategy 1: Dissemination Through Distribution of Materials

The materials referred to here may include kits of equipment, films and other audio-visual aids, as well as books for teachers and pupils, in which the developers have presented all the information which teachers need to grasp both the basic approach to teaching which is advocated and the nature of the content to be taught. The materials are generally the result of several years of development and trial in which successive drafts have been revised in the light of feedback from teachers, but at the end of this period teachers not involved in trials gain access to the programme through the publications. The Oxford Primary Science Project in the United Kingdom [426], the Victorian Primary Science Course in Australia [89] and WISCIP [452] provide examples of this type of dissemination. In these cases there are, of course, meetings with teachers held about the materials but these serve mainly just to announce their existence. Many projects depend to some extent for their dissemination on the message being carried by materials but at the same time employ other strategies. In some cases it is inevitable that, because of lack of mechanisms and resources for running courses, the materials have to stand on their own to a large degree. Where this is recognized, it is often reflected in the kinds of material produced, and may be one reason for giving very specific directions to the teacher, as for example in the Environmental Science Project in Brazil [385].

Through the experience of the early developments in primary science which were pioneers in the process of curriculum innovation as well as in tackling the problems of introducing science into the primary school, we can see the pros and cons of this strategy. In the early 1960s, mechanisms for spreading innovation were rudimentary even in developed countries and it was that experience which led to the growth of the structures found necessary for implementation. For it has become clear that the dependence upon materials alone caters only for 'translocation' (Rudduck and Kelly's analysis mentioned earlier) and does not even include 'communication', since information flows only in one direction; it takes the dissemination process only as far as the phase of 'receptivity'. Information is transferred and received but not much happens that could be called adoption or implementation. Where there is no external motivation in the form of a centrally imposed syllabus, the result has tended to be that no science appears in the school curriculum. In centralized systems, the external incentive to adopt the new material is present but experience shows that teachers' guides are used as recipe books and teachers soon begin to leave out pupil activities, returning to a lecture and demonstration style of teaching. Moreover the written word tends to become a strait-jacket, to be followed because it has behind it the voice of authority of the Ministry or other prestigious body. Teachers' initiative is thus stifled rather than encouraged.

Strategy 2: Presentation Of Teaching Materials Through Courses

As with the first strategy, this is essentially a centre-periphery model, in which the central team, perhaps supplemented by trial teachers or others involved at the development stage, run successive courses for teachers, using the final drafts or published materials. Typically in this strategy the courses consist largely of working through the materials, the teachers experiencing the same activities which they are to use with the children. Other strategies involve teachers' courses but differ in aims, content and rôles of the participants.

The Three Phase Primary Science Project in Papua New Guinea provides a typical example of this strategy [336]. It was appreciated that teachers would not be able to use the project materials without some training; therefore in-service courses were run in six centres which were mostly secondary schools. Trial teachers and college lecturers were among the course staff and the content of the course, mainly consisting of going through the activities, followed closely that used by the central team earlier in preparing trial teachers. At the same time courses were introduced in teacher-training institutions, so that newly qualified teachers came into the schools already prepared in the project materials.

Apart from the overload on those who run the courses, this second strategy suffers from the defect that it does not provide for continued support of teachers as they begin the attempt to implement ideas. The one-off course is often quite effective in providing motivation and results in adoption, but putting intentions into practice invariably brings problems which were unforeseen. If no further support is forthcoming after the course, there is no way for a teacher to obtain help with classroom problems as they arise.

Strategy 3: The Creation Or Use Of Multiple Centres

The deliberate planning to create local bases for courses and subsequent follow-up is the essence of the third strategy for dissemination. In this the direct link from developers to teachers is replaced by a two-stage process of links from the primary centre to a series of secondary centres which then provide lines to teachers - Schon's 'proliferation of centres' model. The Primary Education Improvement project of the Northern States of Nigeria, covering all areas of the curriculum, provides an example of this strategy. The central team is assisted by mobile teacher trainers (MTTs) who are experienced teachers based in the divisions, not at headquarters. Each MTT has assistants who help him with the work of interpreting the ideas of the developers to the teachers, discussing the problems of the teachers and feeding back this information to the central team. Eggleston [90] suggested that the success of the project might well be due to the use of MTTs and proposed a map of a system which could be set up to ensure that further developments can take advantage of this structure (See Figure 1).

A similar system has been set up by MATAI* [147], the Israeli Elementary Science Project, by preparing a team of *madrivot*, or specially trained teachers who are then released from duties in their own schools for about a day each week so that they can visit teachers in a number of neighbouring schools. The *madrivot* help to run courses and meet with the central team to discuss problems of training and use of the materials. The strategy is used also in the Philippines where there are several tiers in the structure. New primary science materials are spread from the Ministry to curriculum co-ordinators in regional offices in a central course. Regional offices then conduct courses for school division supervisors, who in turn prepare teachers at the district level.

* [Elementary Science Teaching Project]

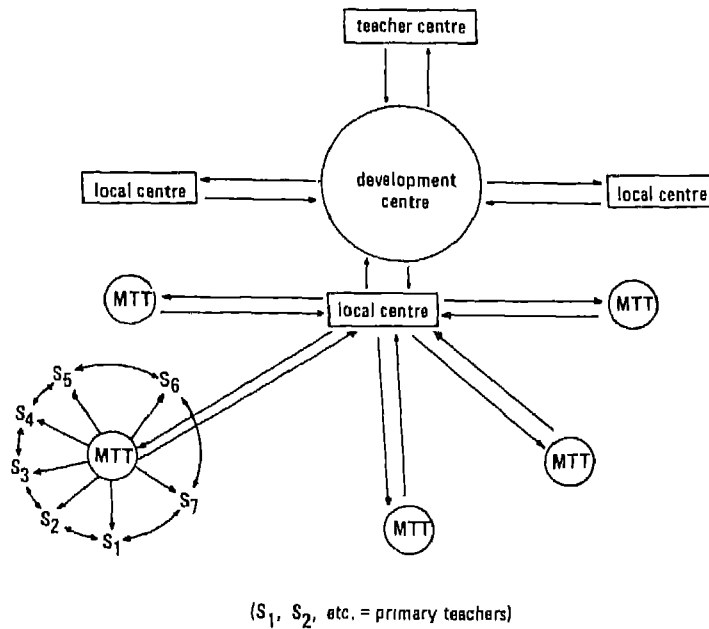


Figure 1: System of Primary Education Improvement project of the Northern States of Nigeria

The strength of this strategy is that it provides potentially long-lasting support for teachers which is informed by links with the central team but not limited by the manpower and time the centre can give. Teachers get help with the practical problems as they arise and the chance to recapitulate the ideas and the philosophy behind them as they work them out in the classroom. The personal contact which the strategy provides plays an important part in this. Thus there is opportunity for dissemination to extend to re-education in a true sense. Implementation is then more likely to reflect progress towards the intentions of the innovation, for the system provides for teachers to have some feed-back and to be motivated to improve their own practice.

However, for its success, this strategy depends upon several factors, such as the continued existence of the central team, and the support of local agencies to provide its resources for the local centres and the MTTs, or their equivalent.

Eggleston [90, p. 15] pointed to the need to give centre wardens five-year contracts and MTTs at least three-year contracts if the Nigerian system was to be viable. Without this commitment the system can be destroyed by lack of continuity in personnel. Re-posting teachers for the purposes of promotion is a practice particularly destructive to dissemination effort.

Strategy 4. Teacher Education

The fourth strategy involves discussion of what is disseminated as well as how it is disseminated and aims for re-education by the nature of the experiences provided in preparatory courses. It attempts to guard against pressures which may later tend to reverse implementation by helping teachers to adapt or develop programmes of work to be of particular relevance to the needs of their children, and by helping teachers to see that scientific thinking and concepts are as basic to children's education as any other parts of the curriculum. It involves sharing with teachers the arguments that lead curriculum developers to propose certain kinds of learning activities in science, the discussion of children's development of scientific ideas, and gives access to the process of innovation instead of just to the product. Teachers are then more likely to be able to use the products effectively, but, more important, to be able to devise ways of helping their children learn through their particular interests and from their own environment.

SEPA has a project for the development of teacher training material which is an example of this strategy. Materials are produced for teacher educators to use in both pre- and in-service courses. They include monographs on topics such as the psychology of learning science, science integration, educational evaluation, using instructional aids and locally available equipment, as well as sources of ideas for primary science [434]. Although teachers are exposed to experiences similar to which they will expose the children, this is only one component of the courses, which also include consideration of how adult thinking about these experiences differ from pupils' and the situations are used to discuss the logic of learning, the nature of teaching, and the importance of involving the child actively in the work. Teachers thus learn about these things through the same methods which they are encouraged to apply, by being themselves involved, they are helped to understand the 'culture of childhood' as well as the 'culture of science' [86]. Discussion and reflection helps them generate ideas about primary science rather than accept these from others.

An important part of this project concerns the training of teacher educators, acknowledging that those in teachers' colleges do not themselves necessarily possess the skills to prepare teachers for using the SEPA approach. These courses for teacher educators aim to help them develop skills of constructing their own curriculum materials, of self-evaluation, of relating to children in a way which enables them to understand the children's thinking, of encouraging children to question, and of improvising equipment. At the same time as developing these skills themselves, the teacher educators are prepared in ways of passing on the skills to their students, the future primary teachers.

Strategy 4 also describes curriculum dissemination in Denmark, where the Royal Danish School of Educational Studies, responsible for curriculum development in grades 1 - 9, runs a series of courses for teachers. In these courses teachers are introduced to, and try out activities from, a range of materials within a context of discussion of relevant learning psychology and of other factors which influence teachers' decisions about their use.

Another example of this strategy is the Progress in Learning Science (PLS) project, United Kingdom [423], which has produced in-service materials aimed to help teachers select or adapt learning experiences to 'match' pupils' stages of development in the ideas involved. In the United Kingdom, teaching materials for primary science produced by funded projects and by publishers are to be found in plenty. The Science 5/13 project [286] (1967-74) alone published twenty six books for teachers, yet the quality and amount of science in primary schools does not reflect the wealth of ideas which are available to teachers. With those resources already in existence, it was clear that adding further to them would be unlikely to bring about implementation. It seemed, rather, to be more likely that development work had been previously too much concerned with the preparation of materials and too little with the preparation of teachers, and PLS was set up to redress this balance. Through the in-service materials it produced, which include video-tapes, audio-tapes and filmstrips as well as written matter, teachers discuss the issues which have to be considered in making decisions about activities and approaches to help children's learning. Whilst the project team existed, leaders were prepared in courses using the 'proliferation of centres' model. After the end of the project funding, these leaders are running courses with the help of the group leaders' book, which also enables further potential leaders to prepare themselves for this role.

CONCLUSIONS

There are not many success stories to be found in the implementation of primary science and, from those which exist, it is not easy to generalize and discover a recipe to guarantee results. A few guidelines can be drawn out of experience so far and it is useful to bring them together at this point. One main problem is to find a way to break the vicious circle of children who do not learn science becoming teachers who do not teach it. Introducing science as a compulsory element in initial training seems an obvious step, yet one which has not been taken in many countries. But this is not the whole solution, even in the long-term, for training institutes are frequently seen as an obstacle to innovation; even if they purport to include science in the training programme, they are criticized for being unaware of new materials and inadequately preparing teachers for their task. Dissemination strategies should be concerned with both in-service and pre-service education, which in the latter case means educating the teacher educators. In both cases, the preparation of teachers and of the teachers of teachers has to be planned on a continuing, rather than on a one-off, basis. Ideas about how to help children's scientific thinking are not static but constantly developing, just as the environment in which children exercise this thinking is also changing. Change is thus of the nature of education and has to be woven into its fabric, not just printed onto its surface.

Equipment and apparatus have to be made available to teachers, but when they are in the form of 'kits', parts get lost or broken and teachers are handicapped unless they can obtain items locally. Reports from Africa and Australia [62] make the point that it is essential for teachers to have money on hand for purchasing materials, but this is often not available because the local authorities do not understand the nature of the work. This suggests dissemination should be directed not only to teachers, but to administrators, to parents, and to the community in general, to provide a supportive and understanding environment for the work in schools. The press and other media have been used effectively for this purpose, as, for example, in Ghana where a television programme for information of parents goes out at peak viewing times, and in Trinidad where curriculum developers have a regular slot in the early morning radio programme. Science fairs are also a popular means of showing the general public the work which children can do if the schools can provide opportunities.

The slowness of uptake of primary science is no doubt in large part due to the fact that it is very difficult. Teachers have been expected to change more radically and rapidly than is reasonable in many eyes. Cohen reports, for example, on the Primary School Scheme for the Northern Territory in Australia that 'The current plans to introduce PSST such that it incorporates elements of CIS, ESS, SCIS and Science 5/13 appear unrealistic and overly ambitious' [62]. We can perhaps learn from this and other experience that it may be better to start from an appraisal of where schools are in relation to the expectations of an innovation. We need to look at the cultural and social setting, too, and ask whether there is any conflict between the goals of a new programme and existing traditions.

Adaptation of programmes and materials to suit local conditions should be encouraged and a structure of support provided for teachers so that, although they will not be able to implement the 'ideal', there will be continued development towards it. There is no harm in having an aim which is hard to reach as long as teachers are not made to feel inadequate for not reaching it all at once. Ways of introducing innovation should, wherever possible, be sought in collaboration with teachers. Perhaps the problems of implementation are caused by the centre of innovation being at a distance from the classroom; bringing it closer could mean that re-education takes place during the development stage. Teachers would not need to be persuaded to introduce changes which tackle problems they themselves have perceived and helped to solve.

9. Towards the implementation of integrated science at the secondary level

Ernos Lambert

Although in their chapter Haggis and Adey have mentioned the existence of eighty-three integrated science projects at the secondary level, what children are in fact learning is often different from what integrated science should be, as described by Booth and Showalter in their chapters. Too many projects are not living up to expectations, have not justified the expenditure of money and other resources, or have even failed to take root. The failure of curriculum projects to make significant impact on the life and learning of young people has been attributed to the gap between the curriculum developers' ideas and the reality of what happens in school [373, p. 14]. Another effective recipe for failure may be the stepwise mechanism (development of materials → dissemination and implementation → evaluation) that has been common until recently; it now seems to be generally agreed that the gap between intention and outcomes will be reduced if all three processes are planned from the start and occur concurrently, as Rutherford has said in his chapter.

Rudduck and Kelly have observed that implementation is a third phase in dissemination, to be preceded by a preparation of persons and institutions for change and the eliciting of a commitment for change [430, p. 99-100]. These phases are facilitated if the innovation bears some obvious relationship to discerned educational needs and is seen to meet those needs in practice. While containing new ideas, it should not make too many inroads into time and energy, or pose serious threat to the status quo, training or capabilities of participants. The support of senior administrators is needed. The innovation should capture interest, and it should be attractively packaged. Participants need to feel that they have made an input, and they should be assured that they will receive adequate support in installing the innovation [410, 445, p. 79-98].

A useful analysis by Havelock [392] identifies three models of diffusion. The *Research, Development and Diffusion (R D and D) model* assumes a logical sequence of activities - the application of research, design of prototypes, field testing, adjustments and modifications, mass production, dissemination and ultimately implementation. Packaged solutions are produced centrally, then distributed to the user. In the *Social Interaction model* the central agency functions as a facilitator of innovations, rather than as an initiator. The success of this model depends to a large extent on personal and professional contacts. The *Problem Solving model* focuses on the identification of needs and the co-operative search for ways of satisfying these needs. It is predicated on the assumption that innovations can and should be tied to user needs. It is interesting to note that some projects, for example Science 5/13, whose initial approach was rooted in the R D and D model, progressed through the Social Interaction model to the Problem Solving one (or to a position close to it). This shift in strategy seems to recognize that there are serious implementation difficulties associated with the R D and D and Social Interaction models.

ADVERTISING AND MARKETING STRATEGIES

Although I am not suggesting that we should adopt Machiavellian strategies, that schemer may have a useful warning for us. He has observed that there is

'... Nothing more difficult to carry out, nor more doubtful of success, nor more dangerous to handle than a new order of things, for the reformer has enemies in all those who profit by the old order and only lukewarm defenders in all those who profit by the new' [408, p. 51].

Integrated science demands adjustments by institutions and individuals who may regard it as a threat to themselves, their status and expertise. The working group felt that initial dissemination efforts should concentrate on winning commitment in some or all of the following: government officials and agencies, heads of schools, teachers and their associations, teacher-trainers, examining boards, parents and parent-teacher associations, pupils, employers and, where appropriate, the university community.

During its development phase, SCISP had a specific programme of dissemination 'to provide information to as wide an audience as possible'. The efforts included circulation of printed materials, meetings with representatives of the committee of Principals of Colleges of Further Education, lectures at science teachers' centres and the Association for Science Education (ASE), residential conferences for inspectors and science advisors, and opportunities to see SCISP in action, at open days for example. SCISP's *Patterns Information Folder*, like ASEP's *Getting to Know Integrated Science*, is a very useful example of an information resource.

The working group recognized that sales strategies will vary widely in different countries and circumstances, but certain methods were seen to have special value. Good contacts at the personal level are effective, as are seminars and conferences involving people from Ministries of Education, universities, teachers, teacher-trainers and administrators. There is a need for wide availability of the reports of international conferences on integrated science education and of a variety of existing good resource materials for integrated science. Radio and television are useful media for dissemination. It now appears to be agreed that teachers and children demand textbooks as part of the support system of an educational programme, and in this field there has been some valuable co-operation between publishers and governments or science teachers' associations. It was the view of the working group that an integrated science programme stands a better chance of being installed and implemented when it is clearly seen to be a thoughtful response to the needs of the community, it is therefore necessary to spell out these needs and the unique contribution of integrated science towards their satisfaction.

The working group advised that strategies for implementation should take cognizance of the educational system of the particular country. That there are radical differences is shown in a 1969 workshop report.

'The Scandinavians operating in terms of a fairly homogeneous culture with a population agreeing on basic values, tend to depend very strongly on consensus or on careful planning ... the English, with greater diversity in values and less centralisation, tend to place much greater emphasis on the selection and training of the appropriate people for innovation rôles ... The Americans ... think in terms of developing tested innovation packages and disseminating these through the free enterprise system and backing them up with the support of funds to get them adopted' [374].

On the surface, other countries appear to present an even greater diversity of educational systems, although the differences are often of degree rather than of kind. There is nevertheless a tendency towards greater centralization in the technologically less advanced countries.

Integrated science is challenging enough and still new enough to demand special attention to advertisement and marketing. Too few projects have used the wide repertoire of available marketing strategies. There is almost everywhere a need for greater co-operation among all groups with a stake in the educational enterprise.

INSTALLATION OF INTEGRATED SCIENCE IN THE CLASSROOM

We come now to the practical concerns of secondary school teachers like myself. These concerns must of course be matters for attention in advertising and marketing, but they demand a variety of additional strategies. A 1972 workshop [325] identified as hindrances to the successful implementation of integrated science. lack of resources and information; the examination, which is often dysfunctional with the aims of the course, inadequate teacher education courses; and lack of adequate training for key people, especially teacher educators. To these I should like to add socio-economic constraints. In 1978, it is worth examining these more closely.

RESOURCES

Successful implementation demands an adequate supply of reasonably qualified human resources (teachers, educational technologists, laboratory help) and material resources including equipment, expensive and routine. Shortage of financial resources seriously limits the provision of these dependent resources and without them integrated science implementation must be, at best, a compromise with circumstances. Inquiry-based, activity-centred courses and really lively classrooms are just not possible without adequate quantities of equipment and hands-on materials and teachers who understand their potential (I shall return later to the question of teachers). Many countries have severe financial problems, but one wonders if priorities are always wisely assigned and if science educators have taken enough trouble to put their case to those who make the budgets. The 1972 Asian workshop stressed the importance of planning for supply of funds for classroom materials when conceiving the innovation and during development of the written materials [325, p. 69]. Local equipment design and production solves some problems, but not always financial ones. When there is shortage of resources, no general solution can be found for every school in every country. One can only hope that things are not as bad as they used to be, when the teacher either described all the 'experiments'¹ or had all the fun by demonstrating them. In his chapter, Ferreyra takes a somewhat more philosophic view.

EXAMINATIONS

Implementation implies achievement of the aims of the curriculum, and public examinations exert great influence on classroom practice in secondary schools as has been pointed out, for example, by Lewis [406, p. 244] and Winter [454, p. 42]. When India failed to recognize this, so that there was a mismatch between the new Physical Science Study Committee course (PSSC) and the old examinations, the curriculum implementation collapsed [425, p. 143]. On similar grounds, Malaysian teachers once called for the suspension of the integrated science programme [61, p. 173-85].

Curriculum innovators may not like public examinations, may consider preoccupation with them to be illogical, but cannot will this preoccupation out of existence. The argument of accountability (to parents, to the school, to employers, to universities, to professions and so on) is difficult to counter as long as these groups use their old yardstick. At least at the secondary level this results in the curriculum being made to fit the process of assessment, rather than the other way round.

It seems, then, that the yardstick will have to be changed, in detail if not in principle. Perhaps we shall have to keep public examinations for a little while yet; but perhaps they can be made to aid good teaching, to reflect rather than to subvert the aims of the new courses. Rogers has written of the sort of questions that need to be asked in the new examinations, questions 'that he can answer if, and only if, he is following the course and achieving some of our aims' [406, p. 264].

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1. I have heard of one school in a country with severe financial problems where the teacher had constructed a wooden model of the ball and ring apparatus!

Some examiners do attempt to match course aims. Osborn [417] reports that CHEMStudy and CBA (Chemical Bond Approach) had healthy effects on Graduate Record Examinations in that the number of questions testing for principles increased from 13 percent to 83 percent over a twenty-two year period. The Nuffield teams saw the importance of having the General Certificate of Education (GCE) examinations prepared by people who had been closely associated with the design of the courses, and the result appears to be a positive effect on teaching and learning. Yet another dimension can be found in the Mode 3 approach to the GCE and Certificate of Secondary Education (CSE) examinations in England and Wales, in these cases, innovation and assessment would both be school-based, so that there should be no conflict about the nature and purposes of examinations vis-à-vis courses. However, it should be recognized that so closed a system may stunt the growth of a programme.

What I have outlined is a spectrum of influence. At one end of this spectrum is an examination which generally has a bad effect on teaching and learning. In the middle is a sort of neutral examination. GCE these days is rather like this; good teaching can and often does go on, but the examination does little to stimulate this and too many teachers fail to perceive that the examinations do indeed test for the ability to think. Finally, at the other end of the spectrum, is the kind of examination which helps teachers to teach better.

The newly formed Caribbean Examinations Council (CXC) intends to be of this last type. The panels which formulate the syllabuses represent a cross-section of educators in the region, and one of the core subjects is integrated science. Fortunately, the empanelling of the integrated science group coincided, more or less, with the formation of CROASE. Recognizing that the new examinations could have a positive effect on education, CROASE acted immediately and decisively in taking to itself the responsibility for curriculum innovation. A CROASE regional workshop set the aims and planned the learning approaches, curriculum design strategies, scientific concepts and integrating themes, production and implementation strategies, and relationship with environmental and social science disciplines. The ways in which the various Ministries of Education would be asked to help were spelt out.

The Workshop also suggested some assessment procedures. The Registrar of CXC was invited to attend for dialogue. CROASE, however, intended to be quite firm that the curriculum development was to be in their own hands but, in the event, firmness proved unnecessary and CXC has always proved not only co-operative but actively helpful towards CROASE. The early dialogue was necessary, though, in order to avoid the development of tension, to clarify the differences between 'syllabus' (CXC's responsibility) and 'curriculum' (CROASE's responsibility), and to delimit the respective roles and responsibilities.

At the workshop the development of mini-curricula was assigned to the various Caribbean territories using, as a basis, an outline [258, p. 116-27] developed at the CEDO/Unesco Caribbean Workshop of 1973. Some of these were made available to the CXC integrated science panel, which used them as starter material for formulating the syllabus. There followed over the next two years a series of CXC and/or CROASE workshops to reorient teachers for integrated science and to produce curriculum elements. A web of interactions has grown up to include not only CXC and CROASE but also the University of the West Indies (members of the Faculties of Education and Natural Science at its various campuses), the Caribbean Regional Science Project (which is providing concrete support to CXC, CROASE and the trial schools) and a publisher (with whom CROASE, drawing on the example of STAN, entered into contract for publication of the trial curriculum materials; these materials have been produced remarkably quickly and distributed free to trial schools).

Trials began in September 1977 and a science teachers' association newsletter describes the CXC input.

'CXC is providing these trial schools with term tests and checklists for assessment of practical skills. Since the test items are explicitly related to the objectives which constitute the syllabus, a global analysis of results allows CXC to evaluate (i.e. find the value of) the syllabus, and the findings will be used when the syllabus is under revision. At the same time, feedback to schools helps teachers

to evaluate their own teaching, and also to diagnose the weaknesses of individual children. Meanwhile, CXC is visiting the schools to get direct feedback from the teachers, and is giving them advice if needed' [362, p. 2].

The significant features of the exercise, as mentioned in this thumbnail report, are (a) the explicit relationship between the test itself and the examination syllabus, (b) the fact that the syllabus is expressed as outcomes of teaching and as developed skills, instead of the more usual facts, and (c) the three-dimensional nature of the trials and feedback.

This case has been outlined in some detail since it is thought to be the first major attempt to install an integrated science programme at the upper secondary level on a regional basis. Dissemination and implementation problems may arise in the future, not least because of the fact that the region contains some fifteen countries. Caribbean educators were opportunistic; there was a new examining body, a new association, a new discipline, and initial interest was wide. Examination reform is taking place parallel to curriculum reform, not subsequent to nor consequent on it. But it is difficult to see how the present stage could have been reached if there had not been a regional association of science teachers, and certainly the situation with the other CXC disciplines is very different. The position with respect to integrated science is one of optimism and continued co-operation.

Reports from Malaysia and Swaziland support other experience that interaction between examining bodies and curriculum developers leads to meaningful examinations and has a progressive (i.e. evolutionary) effect on classroom practice.

TEACHERS AND TEACHER EDUCATION

The classroom teacher, as many of us are quick to realize, is often inadequate. What we do not realize is that our inadequacy is one, not of knowledge of science concepts, but of perception. Haggis, among many, has pointed out that we teach as we were taught, and few of us have been taught science in an integrated way. She has referred to the major changes in approach that are crucial, and to the new demands [271, p. 17] and we need help in perceiving these and in identifying the solutions. One of the best ways of developing perception is the involvement of teachers in curriculum design, as has also been mentioned by Haggis in this volume and elsewhere [e.g. 258].

Showalter [297], seeing the teacher as the key to developing successful integrated science programmes, has posed a set of questions, the answers to which, he says, will determine the success of the teacher and hence of the programme. I am curious, in view of his statements in this book, that he has not added the question 'How thorough a grasp does the teacher have of the nature of science and of scientific enquiry', and I should like to add this question above all. I am equally curious that this matter was not discussed by the working group, since it seems to me to be a crucial question. To achieve this grasp we need a variety of exposures, but one that I have seen to be particularly effective is the unit SCI 1 from the Science Teacher Education Project (STEP) *Activities and Experiences*, given to in-service graduate teachers of some experience.

Apart from perceptions, the teacher will be helped by advice on strategies. Alabi, in his paper submitted to the group, argued that integrated science should be taught by one teacher, and showed how some of the consequent problems could be overcome. For example, single teachers are allotted to each class, but the classes are run at different times. While teacher A (physics specialist) teaches his normal work, teacher B (biology specialist) sits in. The process is reversed when B has to teach. By so doing a transfer factor through a sit-in or listening period refreshes the teachers. Apparently, after three years specialist teachers become confident integrated science teachers. Others feel that team teaching is the answer (e.g. as in some FUSE programmes), but it must be borne in mind that 'team teaching' can easily degenerate into 'turn teaching' and that it breaks down completely when the teachers are socially and/or professionally incompatible.

The preparation of teachers for integrated science has been justifiably of great concern at

conferences and workshops since the Varna Congress [e.g. 220, 258, 271]. In particular, the chapter in this present volume by van der Cingel and Cheong is relevant.

THE SOCIO-CULTURAL CONTEXT

This issue is of great concern in any kind of education, as is illustrated by Case.

"An examiner can be forgiven for doubting the knowledge of a pupil who writes, 'Nitrogen dioxide and sulphur dioxide are acidic, all gases are soluble in water.' In fact, it is translation making mischief, and obscuring the meaning ... if 'both' is substituted for 'all' the sentence regains its intended meaning ... but how is the examiner to know that ciTumbuka¹ has no special word for 'both'?" [269, p. 325-6]

In integrated science education, however, the issues are compounded by the new social concerns that are appearing in curricula. Blum [269, p. 318-22] has drawn attention to some sources of psychological stress that can appear when home and school adopt different stances: science, both product and process, may be at variance with traditional beliefs and ways of doing things; open-endedness and the questioning of all things poses threats to the authority of the family; content selected may serve to heighten an awareness of the state of underdevelopment of the community thereby serving as a depressant to the pupil. Cultural traditions and economic status are, however, not necessarily hindrances. They have been made use of in AES of Israel; in the Turn On Science Programme for native Indian children of the United States; and in the Samoan Sea Study Lab programme, which attempts to stimulate interest in the sea and to heighten awareness of career possibilities for a South Sea island population under threat from metropolitan values.

CONCLUSIONS

Slimming, in a paper to the working group, advanced a model for curriculum implementation, and this is shown in Figure 1. It is worth drawing attention to some of its major features. The

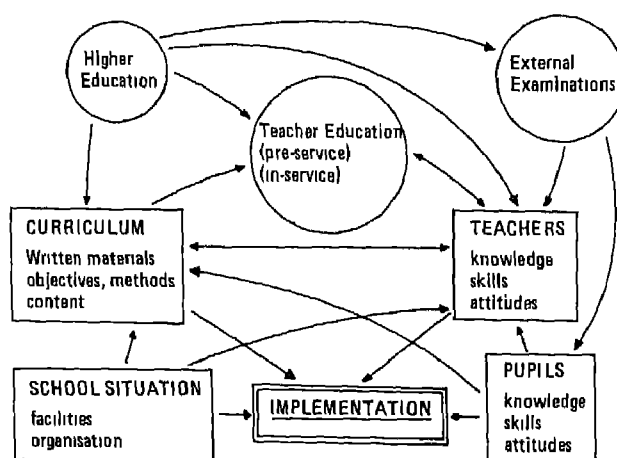


Figure 1: A Model for Curriculum Implementation

(Primary constraints are shown in rectangular boxes, 3 secondary factors have been added and are circled; arrows indicate the action of constraints discussed)

1. ciTumbuka is one of the main languages of Malawi.

model takes account of the needs of pupils and the realities of school; it provides opportunities for teachers to contribute to the development of materials, and it provides mechanisms for the development of pre-service education programmes parallel to the project. Other models are possible, but in the end the working group felt that the diversity of integrated science and of educational systems make it difficult to propose simple, widely applicable, strategies for the introduction and implementation of integrated science at the secondary level. To attempt to do otherwise would have been simplistic, and all the group could do was to draw attention to the issues that need attention.

From our experience to date, however, it is not difficult to agree with Owen who, warning against the imposition of curricula from above, has said

'Changes imposed from external sources may result in overt compliance at the same time as covert resistance ... changes are more likely to be effected and effective if they are introduced slowly ... with people being affected being involved in discussion and much attention being given to persuasion.' [418].



Familiar but different



Television is useful in dissemination



Implementation

10. Strategies and implementation of integrated science education at the post-secondary level

Peter Fensham

Recognition of integrated science education in higher education in the late 1970s is a matter that depends very much on the eye of the beholder. For example, in a small survey to collect information for this chapter, respondents from Malaysia, Netherlands, Japan, Lebanon, Sierra Leone, the United Kingdom and the United States all reported that they knew of few or no examples of such teaching of science. Yet in each of these countries engineers, agriculturalists, technicians and craftsmen all study (after their secondary schooling) various forms of integrated science as part of their education.

In many countries, new programmes have been established which are concerned with training people to work in fields like the environment, health, nutrition, development and small scale industry, and for which a more interdisciplinary background in the sciences is required. Furthermore, science, almost always in an integrated form, is being increasingly introduced into primary (or elementary) and lower secondary education, so that training institutes for teachers are exploring how to provide an integrated experience of science as part of their higher education.

A revolution has occurred in the last decade in the teaching of biology in the senior levels of secondary school in many countries. The new curricula generally involve a highly integrated approach to a number of separate biological sciences, and, in many countries, the most popular (in numbers and interest) science subject in the senior years of school is biology. Likewise, though more slowly, earth science - a more integrated subject than geology - and technological, physical and environmental science are appearing in several countries as new subjects for senior secondary students.

With integrated science existing, and increasing, above and below the division between secondary and higher education, and as secondary and higher education expand in various countries, it is important to review various aspects of integrated science teaching in higher education, and the way in which it contributes to the inevitable problems of transition between these levels of schooling.

INTEGRATED SCIENCE AND THE MILIEU OF HIGHER EDUCATION

There is no doubt that in most countries science in higher education is very strongly controlled by scientists for whom the preservation and promotion of their own separate bodies of knowledge are dominant goals and responsibilities.

This chapter is not intended in any way to suggest that single disciplinary teaching of science for the training of pure chemists, physicists, zoologists, geologists, etc. (or for those who wish to study these fields in depth) is inappropriate. Rather, it is concerned with the many other students in higher education whose courses involve some (or considerable) science study.

Science, like any other field of knowledge, may be defined, for education or for any other purpose, as the product of the social forces exerted by pressure groups of a given time and place who have special needs to sustain. Accordingly, the scientists in these pure science departments usually resist the introduction of integrated science courses in higher education or in secondary schooling, since these courses may detract from the position of their own sciences in education. The resistance extends to service courses in higher education since it is often the numbers of these technological or applied science students that provide the resources the pure departments need to continue their primary existence and its related research. There, the resistance to integrated science in senior secondary education may be associated with a fear that its selective and preparatory functions will not be carried out. Integrated science is perceived as a dilution, if not a distortion, of 'good' disciplinary knowledge.

A common way for disciplinary scientists to exercise control over a science course for service purposes is to teach the usual topics of the pure science at that level, but to add examples of applications throughout. It is important to recognize, however, that such a course is in no way the same as a course in which an application (or a series of them) is taken, and then whatever basic science is involved in it is taught. In the former, the content and sequence of the course is still determined by the logic of the discipline. In the latter, content and sequence will be determined by the application. Students of heating and cooling technology under the former regime would take service courses in applied chemistry and applied physics. Under the latter, the chemical properties of refrigerant and heating substances and of corrosion will be naturally studied along with such obvious physical properties of hydrodynamics as underlie their use in practice.

If technologists are the controlling group of the educational programme, integrated science is likely to be approved.

THE CASE FOR INTEGRATED SCIENCE IN HIGHER EDUCATION

There is little point in arguing an abstract case here for integrated science at the level of higher education. Dale [269] and the report of the ICSU Committee on the Teaching of Science [166] have quite recently given attention to this case. Accordingly, this issue will be dealt with by looking at several groups of students who either commonly learn (or could learn) their science with some degree of integration.

1. Students of Applied Science and Technology.

It has been traditional for students in engineering, metallurgy, mining, etc., to study subjects like 'Properties of Materials', 'Thermodynamics', 'Ore Dressing' and 'Applied Mechanics', all of which are integrations of facts, concepts and principles that have their origins in physics, chemistry or geology. As chemists and physicists devise new materials with interesting properties, or as new applications are developed, new subjects or whole new courses in applied science are emerging. Materials science, polymer technology, bio-engineering, acoustics and materials engineering are just a few examples of emerging, integrated science that are gaining acceptance in higher education.

A corresponding group of biologically-oriented, applied scientists are also trained in higher education. These include agricultural scientists, nutritionists, medical and paramedical personnel (some of whom, like radiographers and optometrists, link physics with physiology and other biological sciences). The explosion of technical knowledge in these fields is such that integration of the basic science education for these students provides a welcome economy of time.

This catalogue of examples of integrated science in higher education should not be taken as indicative of ready acceptance. In most cases, they are the result of struggle in which control was wrested from the pure scientists. Indeed they have often required applied scientists to become the teachers. The integrated science teaching in the Mexican Medical course uses practising physicians with strong science backgrounds to achieve the desired integration.

We can now consider the science education of technologists who for the purpose of clarity in this chapter are distinguished from applied scientists. 'Technologist' here refers to persons whose education is defined by boundaries that arise from a particular skill or particular technology. Thus, an optician and a dietitian are 'technologists', while an optometrist and a nutritionist are 'applied scientists'. A heating engineer is a 'technologist', while a mechanical engineer is an 'applied scientist'. In many countries, polytechnics, colleges of further education, technical colleges, and so on offer training and education which includes integrated science for this type of professional.

As argued above, the knowledge of science is a matter of definition. One reason for the absence of integrated science in the higher education of pure and applied scientists is that it is perceived by the controlling groups as contradictory to the nature of their own disciplines of research for new knowledge. However, when a field of study is defined by a skill or a particular application of technology (rather than knowledge), the contradiction does not emerge.

The appropriateness of the second approach to science teaching described above is seen more clearly if it is restated as in paradigm A,

Paradigm A

primitive or undeveloped skill —————→ knowledge from whatever relevant sciences —————→ improved skill

while the first approach can be simply presented as the build-up of a hierarchy of knowledge, as in paradigm B.

Paradigm B

initial knowledge —————→ developed knowledge —————→ more developed knowledge

2. Vocational Students Such as Home Economics, Art and Craft and Technical Trades.

If we think of vocational education as part of higher education, and it is this in some countries, then there are numerous possibilities for the integration of science education.

For example, in some countries photography students must undertake a one-year introductory course of chemistry that is taken by a great variety of students with quite different intents. However, a number of other countries report science courses for photographers that contain science units more tailored to the vocational needs of this group of students. Paradigm A is their basis. Such a subject unit may be called Chemistry or Photo-Chemistry, but it now incorporates the principles of spectral absorption, optics, and other topics that are not traditionally dealt with in chemistry. A natural integration or interdisciplinary mix appears in the content of the science education because the goal, photographic skill, is itself an integrated application of the concepts of several sciences.

Similar examples of science education exist in most other vocational fields. However, details of these courses are not easily available, and more information is needed. There is a great need for the gathering and dissemination of how integrated science teaching has assisted the education of these students (and those in the other categories) in higher education.

3. Students in Higher Education Not Majoring in a Scientific Field.

In a number of countries, students in non-science programmes in higher education, such as business

education or liberal arts (humanities), are required to undertake some study of science. Here there is a strong case for integrated science. It may well take a form that assists these students to identify with it by making explicit the philosophical, historical or social and economic aspects and consequences of the science. By studying how the sciences together have contributed, and can contribute in the future, the students should be able more easily to comprehend the contribution and limitations of science as a way of knowing and of solving problems. These boundaries of science should not, however, be regarded as only for these 'non-science' students. In the environmental situation facing the world, they are also important ingredients of the education of all scientifically employed personnel - pure and applied alike.

4. Students in Interdisciplinary Fields Such as the Environmental Courses.

A number of vocational fields are now emerging that call for interdisciplinary training that includes the sciences. The environment, human shelter, development and bio-engineering are fields in point. Some of these courses are at the level of first degrees or diplomas while others are reserved for post-graduate study. Two models are in operation here. The first is influenced by such theories of knowledge as that of Phenix [239]. Knowledge is not perceived as separate from, or paramount over the learner. The learner, as a whole person, is the object of education. Knowledge, acquired from and associated with other persons, can be used as a means of enlarging the learner. This model will strongly associate the acquisition of knowledge with experience, with personal decisions, with attempts to articulate the significance of the learning to the learner, and so on. Disciplinary knowledge does not, in this model, stand in isolation from knowledge from other disciplines and sources. The students' science education will be aimed at putting together ecological principles, knowledge of the earth's resources, and the natural laws of physics and of chemistry. The integration will not stop at the sciences, however, and it will involve many other aspects of human knowledge (Parsegian et al, [419]).

The second model tends to underlie most post-graduate courses. This model is a building block one in which the disciplines are firmly recognized, but a real attempt is made to put them together. One such 'interdisciplinary' course is the post-graduate course at Mahidol University in Thailand for environmental personnel. This course aims to turn out 'integrationists', i.e. persons who know and understand the strengths and skills of the various science and other disciplines and how they can be applied in team work to tackle real life situations. The course for liberal studies in science developed by Jevons [402] at Manchester University (United Kingdom) also belongs within this model.

5. Students Preparing for Primary Teaching

There is widespread interest in integrated science in the education of primary or elementary teachers. Science education of any sort for these students seems to have difficulties in most countries. The students, in general, have very weak science backgrounds from secondary schools and negative attitudes often associated with personal failure at such studies. A number of programmes have attempted to overcome these inadequacies by offering integrated approaches to science which, at least, are not simply a re-presentation of the disciplinary view of science these students have already rejected. A degree of integration that seems to be possible for the teacher educators of these students is a physical science unit integrating content from chemical, physical and sometimes earth sciences, and an environmental or ecological unit embracing various biological sciences.

Nevertheless, the inability of many science teacher educators (often excellent disciplinary secondary teachers by background) to manifest the integration they are aiming at in their students remains a problem. The so-called integrated courses often become 'sum' courses, (e.g. physical science = physics + chemistry) taught by different staff. They also often seem to be constrained to conform to a disciplinary view of academic studies for recognition purposes, because very few examples of integrated science teaching in prestigious institutions are known.

6. Students Preparing for Secondary Teaching

The common pattern for these teachers has been and remains highly disciplinary. However, a number of interesting developments were reported.

Surrey University (United Kingdom) has established a four-year science degree (including teacher education) which has two possibilities for integrated science education. There is a major study of physical science and then some modules of it can be replaced by Science and Society, Computing Science or Economics.

The University of Roskilde (Denmark) also has a programme for secondary teachers which builds on two initial years of integrated natural science study. This is followed by disciplinary studies in the final years as well as educational studies for the teaching qualification.

A small number of teachers in several countries undertakes science studies via naturally integrated science courses that are primarily for agricultural scientists or technologists as in group 1 above. These appear to be so successful in developing competencies and confidence in a number of science disciplines that the main stream of science teacher preparation could learn from the almost accidental but effective backgrounds that this sort of science teacher has acquired. Conversely, as mentioned earlier, generalists, like agricultural scientists, could be employed to teach science to intending teachers.

Summary

In a useful summary of integration in higher education, much of which relates to science [173], Jevons and Turner identify five categories of integration, dominant discipline, cross-discipline, cross-culture, problem and disintegration. In the groups discussed, all five approaches exist somewhere in higher science education.

PROBLEMS OF TRANSITION ARISING FROM INTEGRATED SCIENCE EDUCATION

In moving from secondary to tertiary education, three situations can be considered in which integrated science is involved.

	<u>Situation I</u>	<u>Situation II</u>	<u>Situation III</u>
<i>Tertiary Education</i>	<i>Integrated Science</i>	<i>Disciplinary Science</i>	<i>Integrated Science</i>
	↑	↑	↑
<i>Secondary Education</i>	<i>Disciplinary Science</i>	<i>Integrated Science</i>	<i>Integrated Science</i>

The pre-eminent problem faced in the promotion of integrated science at these levels is the claim that the earlier stage will have inadequately prepared the students for the second stage. Undoubtedly there are gaps in the students' knowledge that may traditionally have been assumed. Whether these are so serious or so hard to remedy that they warrant the usual resistance to integrated courses is much more doubtful. As we shall see, there are many solutions and it is important to realize that the advantages of integrated science must be kept in mind to balance the scene. Furthermore, science educators in higher education, without integrated teaching, are now confronted with the problem of inadequate preparation from poor schooling, affirmative action by compensatory programmes, and so on, so it is not confined to the integrated science situation. Some other problems of the first two 'mixed' situations are now discussed.

Situation I - Other Problems

(i) There is considerable evidence that transfer of learning from one sector of study to another is a very difficult task. The skills of ratio and proportion in mathematics are not easily used

by students in the chemical context of stoichiometry. Atomic structure learnt in physics is not easily transferred when the same learner is confronted with spectral aspects of chemistry. Accordingly, many students whose learning of scientific ideas, concepts and principles has been within the tight confines of disciplinary science have difficulty in identifying and interrelating these things when they are presented in more integrated contexts.

(ii) Confusion is created for both students and teachers by language and symbols that differ from those used in their previous separate sciences.

(iii) The disciplinary sciences have largely developed through the use of 'atomistic' models of natural phenomena. Students who have learnt these disciplines, and hence this world view, have difficulty in comprehending the more interactive or holistic models that often underlie the way integrated science is taught in ecologically or environmentally oriented courses in higher education.

(iv) Disciplinary science in secondary schooling rarely allows substantial studies in the physical, biological, earth and behavioural sciences. Most students moving from such secondary studies to integrated science in higher education thus have an unbalanced background of knowledge and poor motivation for their new courses.

(v) Integrated science for, say, primary teachers, while at least different from the science of their previous failure, does pose an initial problem of apparent further difficulty simply because it is different.

Situation II - Other Problems

(i) Students whose secondary science education has been integrated will almost inevitably have covered less content and in a less sequential manner than the disciplinary teaching of the sciences (particularly physics and chemistry) in higher education normally assumes.

(ii) The problem just raised would appear to have a simple solution, once it is recognized, and introductory or bridging programmes for these weaknesses are offered as has been tried in countries where there are serious shortages of science students or where recurrent, compensatory or general education are taken seriously as legitimate functions for higher education. However, the solutions have not proved so easy in practice. Science educators at this level do not find it easy to adapt to such students. There are also often constraints on course length and student funding that mean these relatively 'weak' students face the depressing prospect of additional bridging programmes on top of the normal first year programmes. Drop-out and failure tend to be high unless degree credits are organized in a way that allows these 'remedial' units to contribute credit towards their qualification.

(iii) Integrated science in secondary school has often achieved a sense of relevance, excitement and reality in students. After such a schooling the disciplinary study of sciences like physics and chemistry in higher education, with their very slow sequential, abstract and tight knowledge structures, seem irrelevant and uninspiring. With low motivation, adequate achievement in these difficult subjects is not likely.

STRATEGIES FOR TEACHING INTEGRATED SCIENCE

A. Co-ordinated Sum of Separate Sciences

One obvious and perhaps minimal strategy is to teach the disciplines separately, but to arrange for the teachers involved to co-operate by the sequence of their topics, by using common nomenclature and symbols, and by not duplicating topics (e.g. kinetic theory in both chemistry and physics). The Union of Soviet Socialist Republics reported such a strategy in the training of science teachers, most of whom are responsible for teaching two science disciplines. The significance of this apparently low level of integration should not be underestimated since it has not been achieved in many institutions.

B. Separate Sciences With Shared Sections

Further co-operation occurs when two or more separate science courses agree to share a unit on a particular topic. The University of Sussex (United Kingdom), from its inception, has had this type of integration between chemistry and physics with units for statistical mechanics, thermodynamics, basic spectroscopy and crystallography. Modular course programmes in higher education make such co-operation more possible.

C. Thematic Studies

Themes, such as a technology, or a wide reaching concept, or a natural phenomenon, or a particular environment, are natural means for integrated science teaching to emerge. Such a strategy is uncommon for students of pure science in higher education. An exception is perhaps biology in the initial year of higher education, where the large theme approach, so successful in senior secondary education, is being tried. However, for technologists, environmentalists, and primary school teachers there are some very encouraging reports that a thematic approach can also be used very effectively.

Paradigm A is a particular form of thematic approach, and the other types of theme also assist educators and lecturers to restructure the knowledge of science so that integration is possible. A theme like 'Water and Other Liquids' is an interesting one for conjecturing how, in higher education, you would teach it to students in, say, groups 3, 4, 5 or 6 above.

D. Project Studies.

The use of projects, either laboratory-based, or associated with field trips, has recently been a popular strategy with integrative potential. The Nuffield Foundation Group for Research and Innovation in Higher Education in a series of newsletters, 1973 to 1975, reported numerous British examples of projects. Project work in small groups is a dominant working method in the integrated course at Roskilde University; the projects are designed to help the student become aware of the application of science, the significance of experimental work in theory formulation and the planning and implementation of experimental studies - common issues that cross the scientific disciplines. Another form of successful project has been to charge a group of student teachers with diverse science backgrounds with designing a curriculum unit (and its attendant materials) on some real life situation for use in an appropriate level of school.

E. Systems Approach

A useful approach with quite different groups of students is the systems model. This deals with complex situations that are multivariate and interactive by regarding them as receiving inputs that lead to observed outputs, as shown in Figure 1. The fine detail of these relationships is

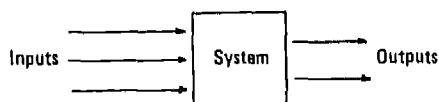


Figure 1. The input-output model of the systems approach

not the primary concern of the model. Because of its simplicity, the approach has recently been tried with the 'difficult' group 5 of students mentioned earlier. One of its strengths is its universality across the sciences, which are fields of human knowledge that are full of relationships between variables that can be regarded as the inputs and outputs. It becomes only a matter

of degree that some relations are tightly expressed via mathematical functions, (e.g. force on, and acceleration of, a mass system) and others are more descriptively related, (e.g. protein intake to and health of a community).

Integrated science courses that exemplify the systems approach are the Man-made World [384] and Man and the Physical World, a recent Australian one [456].

F. Use Of Resources And Software

Simulation games and computer-assisted learning are more recent teaching strategies that can substitute for difficult or inaccessible aspects of real situations that could or should be part of integrated science education. However, much can also be done in traditional teaching if less usual resources for integrated science, e.g. the *Ascent of Man* television series by Bronowski, British Broadcasting Corporation (BBC), are introduced to students.

G. Student Created Integration

One organizational strategy in higher education enables students to create for themselves an integration of science education that is beyond the capacity of their separate lecturers. If there are comparatively short modules of study and not too many defined sequences or compulsory units, students can then put together the separate units of disciplinary study to form a degree course that meets their own needs, interests and abilities. Once again, biological scientists have been leaders in this strategy, but it is becoming increasingly possible in the physical sciences as some of the old assumptions about their sequential knowledge are challenged.

Each of these strategies has certain strengths and weaknesses. For example, a thematic approach throughout a course can be repetitious. It may, however, provide reinforcement that is lacking in the rapid linear development of many science courses. Projects and themes are good motivational devices for learning with real understanding - they are also likely to omit what some might regard as important foundational knowledge. The systems approach is elegant but can over-generalize and over-simplify.

TEACHING STRATEGIES AIMED AT THE PROBLEMS OF TRANSITION

'Integration', however the word is used, does imply a bringing together. It is interesting, thus, to note the use in integrated science teaching of *group learning* or *co-operative student study* - modes of teaching and learning that bring together teachers and learners.

Bridging programmes are means of remedying the gaps in a student's knowledge that are common to integrated science. As an alternative to manning these expensive and often ineffective programmes, there is the use of *self-instructional packages* which diagnose and cover these essential pieces of prior science knowledge.

The acceptance by institutions of higher education that it ought to be possible to begin the serious study of science at this level does mean that introductory courses need to be offered that provide the essential skills that the standard course specifically needs. Gilbert at the University of Surrey (United Kingdom), Linke at Flinders University (South Australia), and Beeson at Rusden College (Victoria, Australia), have used this approach to overcome the transition problems of very different groups of students in higher science education - science students, non-science students entering medical studies, and middle level technicians.

11. The implementation of integrated science

James Rutherford

Abstract of plenary paper

Recent attempts to bring about integrated science instruction generally have three characteristics; they are curriculum oriented, serially ordered, and locally adaptive. The stated purposes of these approaches is to achieve the teaching of integrated science course in the schools. In a typical scheme an integrated science course based on one or another organizing principle is developed and tested; dissemination efforts are then mounted to inform potential school or college users of the existence and value of the integrated curriculum, finally, steps are taken, usually through teacher training, to foster proper implementation of the new curriculum. This approach, in which development and execution are separated, has not been altogether successful.

Another approach has been tried out that is more complex and less direct, but that holds out a higher probability of achieving enduring results. Rather than narrowly focusing on the goal of introducing integrated science curricula into schools, this model adopts the more general purpose of improving school science instruction, toward which end integrated science is seen as being instrumental. A co-operative systems-approach is advocated that tries to deal simultaneously with all major aspects of the task instead of proceeding step by step, from curriculum development to implementation. To the extent possible, all persons and institutions having a stake in the outcome - teachers, science supervisors, school principals, curriculum developers, educational researchers, university scientists, teacher educators, etc. - are brought into the effort at the very beginning.

Needs assessment, involving teachers and administrators, in-service and pre-service programmes, and the building of administrative and community support, all proceed together. Operationally this approach is teacher-oriented rather than curriculum-oriented because it is based on the belief that effective implementation of any novel curriculum is unlikely without teacher understanding rooted in experience.

Project City Science, a project in New York City funded by the National Science Foundation, has as its goal the improvement of junior high school science instruction in the inner city. It will serve as an actual example of how curriculum development and implementation can occur simultaneously in a general problem-solving context.

The full text of this paper (26 pages with references) is available from the author.

12. Education of teachers for integrated science

Nelis van der Cingel and Cheong Siew Yoong

NEEDS AND STRATEGIES

Nelis van der Cingel

The subject of this chapter is diffuse in many ways because neither 'integrated science' nor 'teacher education' has been satisfactorily defined [40, 271] and because we are dealing with a subject that was the theme of the whole Maryland Conference [271]. Nearly every chapter in this present volume identifies teacher education for integrated science as a critical area of attention, and there is agreement about the need for a continuous education, an initial training phase to be followed by in-service education. Teachers need knowledge, skills and attitudes related to their profession as well as to science of the kind described by Booth and Showalter in their chapters and exemplified throughout this book.

In this chapter the main emphasis will be on two questions discussed by the working group: what special needs are associated with the role of teachers of integrated science and what science content background is appropriate for prospective teachers of integrated science? There will also be some attention to other questions discussed by the group, although Cheong will treat these more fully: what special efforts have been made to prepare teachers of integrated science at both pre-service and in-service levels and what innovative approaches to preparation of teachers for integrated science might be tried in the future?

Most of the working group participants were knowledgeable in the secondary field, so the emphasis lies there, but there is also attention to the preparation of primary teachers, a matter that has received some attention from Harlen in her chapter on implementation. We were not able to consider the preparation of university teachers of integrated science, or of teacher educators, but these are matters that deserve consideration at a future conference. In our world-wide treatment, we have classified among developing countries, in the context of integrated science education, several countries in Europe which, in other contexts, are highly developed.

DEVELOPMENTS IN SCIENCE TEACHING AND TEACHER EDUCATION

In their chapters, Gadsden and co-workers and Haggis and Adey have shown how much variety exists in science curricula developed since the 1950s. Nevertheless, almost every science curriculum project nowadays seems to have the following characteristics: more stress than before on concepts and processes; use of a variety of educational techniques ranging from the use of audio-visual strategies to techniques of formulating objectives; an influence of learning theories, e.g. of Bruner, Ausubel, Piaget and Vygotsky; application of new teaching techniques and methods in a shift from mainly verbal instruction to the use of several senses; discovery-learning and openness in the teaching-learning situation, and involvement of students in the decision-making; more attention to the social relevance of the applications of science and to concern for the environment and for man (the chapters by Dyasi, Hofstein and Lewis treat these issues in detail);

a trend towards integration either in the use of integrative principles in the separately taught science subjects or by integrated science *sensu stricto*; and a trend to both individualization and socialization at the same time - each student is recognized as an individual and a unique person, developing in a society in which he has to find his niche. Some of these have been identified independently by Haggis and Adey as trends rather than as commonalities, and we might conclude that in these cases the trends have approached completion. We might at this point twist the theme of the Nijmegen Conference and ask 'where were we going, and have we got there?'

Teacher education, too, has been changing. Meyer has given a thorough picture of trends in biology teacher education in 1975 [220], and most of what he says is general enough to apply to integrated science teaching (see p. 78). The twenty trends identified by Meyer are supported by a lot of evidence collected in an analysis of the literature, by a questionnaire, and by my own experience with teacher training in the Netherlands and in the United Kingdom. Nevertheless, one can safely say that there is a long way to go before these trends become common practice in science teacher education world-wide.

SPECIAL NEEDS OF TEACHERS OF INTEGRATED SCIENCE

There is room here for only a few examples of attention to this issue. In the United States, state requirements for science teachers were surveyed in 1968 by Williamson and co-workers [429]; and in 1970 and 1971 the American Association for the Advancement of Science (AAAS) produced guidelines for the preparation of elementary and secondary school teachers [359, 360]. In 1973 a Caribbean workshop produced a very complete and detailed list of aims and behavioural objectives, and about forty activities to achieve these aims [258]. The sixty-three objectives relate to principles of learning theory, psychology and child development; the location and use of resource materials; knowledge and understanding of the community; laboratory and classroom management; aims and objectives; communication with pupils, evaluation; philosophy of science education; and attitudes and interests of integrated science teachers. Similar lists are available from other parts of the world, and in proposals for the restructuring of curricula in teacher education in the universities of the Netherlands.

In short, it is clear from the literature that there has been a great deal of thinking about requirements, guidelines, objectives, and so on, and there is no lack of good ideas in general or specific terms about the education of science teachers. The trends and philosophies seem clear; if, however, the reality of most teacher education is not reflected, we should realize that the function of such statements is to generate ideas, to influence people, to serve as guidelines, not to provide prescriptions.

A persistent theme in the working group discussion was the development of *attitudes* in teachers of integrated science. It was felt that the need for the teacher to look beyond the confines of scientific content requires an adjustment of attitude. The teacher should understand and show interest in the culture, interests, language and values of the pupil. Lemke's submitted paper especially analysed language and communication problems in science teaching. Participants saw the environment as a resource and common ground between teacher and pupils. The teacher must be helped to acquire economic, political and agricultural *sensitivity* in relation to scientific activity. The integrated science teacher might be required to discuss the notion of 'quality of life', for example, in relation to decision-making in the resolution of persistent human problems.

It was thought important that the teacher of integrated science should develop a non-defensive *teaching style* so as to facilitate interdisciplinary activities with colleagues and to gain co-operation from pupils. Aspects of that preferred style are the encouragement of criticism from colleagues and pupils, and the use of team-teaching.

Among the *special competencies* of integrated science teachers, it was suggested that the teacher should be given the skills necessary to make a sensible selection of content (problems/tasks) which match the skills, interests and abilities of pupils (the contribution of learning theory and

theories of development were thought important in this respect) and should be a good manager of resources, e.g. be able to recognize the potentials of existing aids.

Teacher background was seen as especially important. Knowledge of, or experience with, alternative employment was thought valuable, as well as the teacher's own exposure to teaching when he was a student.

SCIENCE CONTENT FOR PROSPECTIVE TEACHERS OF INTEGRATED SCIENCE

This is part of the needs issue discussed above, but there are reasons for treating it separately. It is always the key problem in discussions about the adoption of integrated science courses.

There are

'... two well-defined positions concerning the competence of the science teacher. At one extreme is the concept that the science teacher does not need to know science, but merely how to teach. At the other extreme is the concept that all that is necessary for a competent science teacher is a command of a great body of science content, denying that there is such an entity as professional competence'. [429].

It is unlikely that anyone will defend either of the extremes. But can we arrive at an optimum competence in science for the elementary school teacher and the secondary school teacher? If we start from what we suppose to be the right objectives for the education of teachers, can we trace back what that means in terms of science content?

The European Communities Biologists Association (ECBA) used general terms to sum up the basic demands for biologists, and saw them as also basic for prospective teachers [98] (see p. 79). The necessary attitudes that should be fostered by basic curricula were listed, and here ECBA made specific mention of integrated science. These skills and attitudes that scientists desire as the outcome of science education at the tertiary level are well worth bearing in mind as appropriate to science courses for teachers at both of the levels that educate for general purposes, the elementary school and the secondary school. It is worth comparing them with what educators see as the aims and objectives of integrated science teaching, a general view being provided by Iolo Williams' clock of aims suggested at the 1973 Caribbean workshop and shown in Figure 1 [258]. Even if we do not rate every item in both statements as 'very important', and when we take into account the fact that the ECBA scientists limited themselves to the general non-professional skills and attitudes, we notice that there is much overlap between the two sets of statements, but also important differences.

Perhaps the best we can say is that the science background for every teacher of integrated science should at least reflect what science really is: therefore, in the training of teachers, we have to develop the skills and attitudes that can be considered typical for science. The best way to do this is by using with our students the open practical working methods of science in the same way as we want them to be used in the classroom.

One sub-group at the Conference took special responsibility for the issue of science competence. They made the following assumptions. First, teaching *fundamental science* deals with concepts, models and processes developed by scientists in each discipline; teaching *integrated science* deals with the unity of the universe and how man interprets what he observes. Second, traditional university courses produce 'disintegrated' scientists, i.e. people who perceive the parts but not the whole; they therefore are not suitably adapted to train teachers of integrated science. Third, prospective teachers of integrated science in pre-service training should receive training in the basic concepts, models and processes of the various disciplines. Finally, teachers must experience the same problems as pupils in respect of, for example, open-ended problems and decision-making.

Working from these assumptions, the sub-group produced a model that might be helpful in designing four-year training courses. The model is shown in Figure 2.

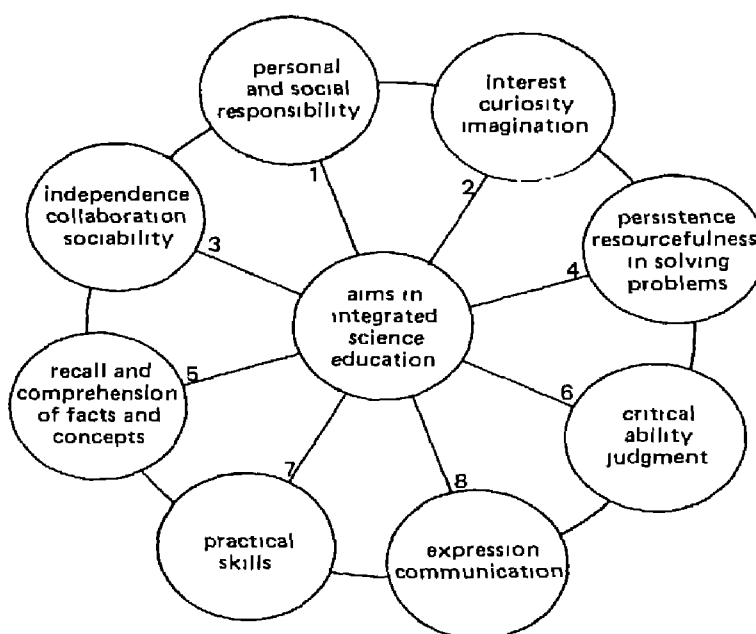


Figure 1. Clock of aims of integrated science teaching

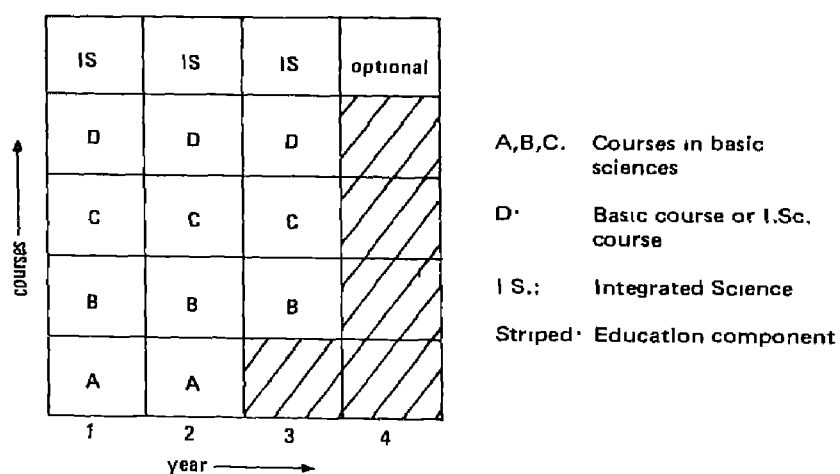


Figure 2: Model for the design of a 4-year teacher education course

It will be seen that the course should contain at least three units in integrated science. An alternative structure would be to have the education elements spread throughout the four years. The optional unit in the final year might be either basic or integrated science, according to the requirement of the student teacher. The best possible way to arrange the science content might be according to universal themes like change, energy, equilibrium and entropy.

In-service training should be related to the school science curriculum and tuned to the appropriate level of the teacher, and should offer a variety of methods and content to up-grade the teacher. If at the same time the teacher were to undertake critical studies of the school course, the quality of that course might be improved.

The group emphasized that converting subject specialist teachers is difficult and, in the long run, an inadequate method of providing a supply of competent integrated science teachers.

SPECIAL EFFORTS TO PREPARE TEACHERS OF INTEGRATED SCIENCE

In the space of this chapter it is not possible to report strategies in the field of teacher training, nor even to give examples or models from the literature.

However, recent literature on science teacher education, e.g. Capie [371, p. 190] does seem consistently to convey an atmosphere of doubt about what has been achieved so far. Pre-service education is judged inefficient since real teaching experience is lacking or comes too late. Unless teaching experience comes early in the course, and is the core of the curriculum, students cannot be expected to ask the questions which could give motivation and direction for their preparatory studies. In-service training, on the other hand, seems to fail if it does not take into consideration the fact that the needs of the teachers differ according to their background and what they are teaching now.

It does seem possible to identify some aspects crucial for success, e.g. the relation between the medium and the message, that is between the objectives and the teaching methods used in teacher training; and the involvement of the prospective teacher in the planning - control by the teachers of their own development; unique interests, aspirations and strengths of each learner should be taken into account in the planning of the instruction.

At the Caribbean Workshop, Ibstedt introduced the concept of the Unit Package [258]. This is interesting in that it relates the different levels of instruction, those of the teacher educator, the student and the pupil. This can serve as an example of attempts to relate the method of instruction of the prospective teacher with his tasks in the school. Another example is Berkeley's Workshop on Reasoning Patterns. This uses the learning cycle as a method of learning about the learning cycle and concepts from the area of cognitive development [174]. Still more examples can be found in STEP and ASTEP.

From my own experience I wish to illustrate how, at pre-service level, experiences in the school can be guided in a more professional way.

TEACHING PRACTICE - THE CORE OF THE CURRICULUM

A profession is characterized by a scientifically founded body of knowledge, insights, skills and experiences essential for the exercising of that profession. Another characteristic of a profession is the further development of the professional during practice. An education for the teaching profession therefore needs to introduce this knowledge and these skills and insights, and to give the student teacher the opportunity to gain enough experience in practising to be able to embark independently on his career.

That is why teaching practice has to be the core of the curriculum. Left on his own with his

pupils, the young teacher must have enough confidence and skill to do his job without fighting a battle against himself or his pupils. Teaching practice should offer learning situations which confront the student teacher with experiences, systematically and under guidance.

For the last few years, teaching practice in the Netherlands has provided such guided experience using the following strategies. Groups of two or three students work together in the same school under guidance from the same tutor from the institute and the same co-tutor from the school. The lessons of the student teachers and the co-tutor are observed by this whole group, and can therefore be analysed from different points of view. The co-tutor is specially trained for his job as a guide in the development of a personal teaching style of each student teacher. The activities of the student teachers in the school are carefully planned, and there is a gradual development of responsibilities. The training in the institute is integrated with the teaching practice and this in turn serves as a guide to the theory of education.

Within the scope of this chapter, it is impossible to survey all aspects of teaching practice as it is under development in the Netherlands, but from my own experience I should like to deal particularly with two principles.

The first of these concerns self-evaluation. Since student teachers will be fully responsible for all their teaching as soon as they get a job, they must be able to evaluate their own teaching. Therefore self-evaluation has to be fostered by tutor and co-tutor as systematically as possible. One of the strategies is to foster self-confidence by making possible a gradual development of responsibility. The other strategy is to make the students responsible for their own learning by making a contract with each student individually.

The second principle concerns the strategy for discussing the lessons given by the student. It is necessary to avoid judging him by criteria based on the personal teaching style of the observing 'judge' and to avoid making the student defensive as a result of criticism of his teaching behaviour - students on the defence are not likely to learn from their experience. A useful approach is to make all the participants in the discussion as vulnerable as the student who gave the lesson. The students of the co-operating team are asked to formulate clear objectives for their observations, or to use objectives formulated by the student who teaches, and the observations are used as the basis of the discussions. The observers are first asked to state, as objectively as possible, what they observed, which method of observation they used and their conclusions from the observations. Then each participant in the discussion has the right to ask for more information about the observations and, as a next step, the observation is evaluated. What was the value of the objective chosen? What are the pros and cons of the method used? What is the worth of the conclusion? After each observer in turn has reported his findings the lesson appears to be discussed very thoroughly and very honestly, because of agreement about what happened. It often turns out that no further discussion and criticism are needed.

POSSIBLE FUTURE INNOVATIONS IN THE PREPARATION OF TEACHERS OF INTEGRATED SCIENCE

Some guidelines may be found from Meyer's list of trends in teacher education. But we cannot rely solely on following the trends. If we relate this issue to the foregoing one, we must ask what evidence we can find in our own experiences to suggest that we are moving in the right direction, from our own experience we may be able to select the important trends for our own situations.

We must also keep in our minds the central place of the needs and concerns of student teachers when we plan activities. These needs will certainly relate to self-confidence, teaching tasks, content, and children.

We should also remember that prospective teachers can find a job in several parts of the school system. They can become involved in educational policy, curriculum development on a national or regional scale, teaching and planning for teaching, or make a variety of other contributions to education. If innovation in teacher education is to have real impact, every part of the educational system should be involved. We need a flexible system of teacher education in which

student teachers can become acquainted with, and involved in, work in different areas. We must invite people from all these areas to participate in teacher education, and we must allow our students to assist and learn in different situations. Why should they not spend part of the time at a teachers' centre, with the local education authority, with an inspector, or with an architect of school buildings?

Nor should we forget that children can be involved in the education of teachers in a more responsible way than just as pupils. For example, they can help in evaluating lessons given by students. They can be brought into institutes for microteaching and other demonstrations. The same holds for teachers. They can participate in different ways in pre- and in-service training, because of their first-hand knowledge of different aspects of teaching.

More than in the past, pre- and in-service training should be related to each other. Frey has suggested a model in which teaching practice in the successive years of teacher education increases gradually, and eventually evolves into full-time employment with still 10 percent of the time allocated for the teacher's continuous education [117].

The working group formulated some guidelines for the future development of methods and materials for both the training of teachers of integrated science and the education of teacher trainers. A dominant theme identified as a pattern for the future is the greater interaction of school, student teacher, and teacher trainer. Work in the field of alternative technology (United Kingdom) was cited as an example. The after-care of newly trained teachers was seen as both a co-operative venture and a necessity for the proper development of the teacher. The Schools Council Project, Home Economics in the Middle Years (United Kingdom), and PRONAMEC (Peru) illustrate possible ways of doing this.

For the teacher, emphasis needs to be placed on the art of managing large classes and mixed-ability groups, skill in improvising equipment and activities, awareness of the impact of university-style science courses on the student teacher's view of science and his teaching, a recognition of the low level of competence of the newly qualified teacher and of his need for further support and training, the role of external agencies in raising that level of competence (for example, teachers' centres) and the integration of content and method in training programmes. The effectiveness of the teacher educator might be improved by recognizing the need to involve the school more in the training process, by making the training more school-based. In addition, the teacher educator might profitably adopt rôles more in sympathy with the rôle he suggests for the teacher; recognize the value of the pupil-teacher relationship as a source for instruction; look to other professions, like the medical profession, for alternative models of training new recruits at the internship (induction) level; become more involved in in-service work, particularly after-care of the newly qualified teacher; develop more resources for teacher education (the STEP and ASTEP materials were cited; individualized instruction programmes were suggested as a promising target for development); and recognize the need for more experience of the community into which the teacher will be placed.

The working group's guidelines stimulate further comment. If we really want professional teacher educators, we need a thorough analysis of the kind of expertise necessary for this profession. Although we teacher educators have our philosophies, we lack insight into the objectives of teacher education, and these objectives have seldom been the subject of research. There is at present in the Netherlands a very ambitious project on this matter [232]. However, knowing what teachers need is only the beginning of the answer to the question of what teacher educators need. A first step is the production of materials like those of STEP and ASTEP, but many more steps are needed before we have a theory of teacher education.

In institutes of teacher education, we can safely say that if subject teachers feel responsibility for only their own part of the curriculum, and not for the way in which their students will eventually teach the subject, training is ineffective. This is often the case in universities, whose teachers are selected more often on the basis of research than on their teaching capability. University teachers seldom possess a teaching certificate and are often not interested in teaching quality. My own experience in teacher education in a university confirms

that student teachers do not really understand what they have been taught before the subject matter has to be applied, for example in the preparation of lessons. This suggests that university teachers have something to learn from the principles of education about the way in which they should convey subject matter.

When a student is asked to apply in a different setting what he has been taught, he comes to understand it better. This alone would justify integration of subject courses and teacher training courses. Additionally, integrated courses will mean more harmonious education of teachers. Such integrated courses will very soon be under way in Netherlands universities, leading to a much more professional approach to teacher training. Some universities have also developed courses to train their academic staff and there is discussion about making such courses obligatory.

POSTSCRIPT

The working group had to restrict its discussions, but was aware that other important issues need to be faced, such as the following problems: selection of candidates as a means of influencing the quality of education, especially at the primary level; national or social development as reflected, for example, in the imbalance between offer and demand within the educational service (what, for instance, is the relationship between teaching methods and the number of children in a classroom?); and individual versus societal needs - the problem of harmonizing national policy and professionalism in teacher training.

It seems well established that there is a gap between the perceptions and aspirations of participants at conferences like this and classroom practice. One does not have to extrapolate far to conclude that teacher educators have so far failed in the preparation of their students. This must be a key area for attention.



TRENDS IN BIOLOGY TEACHER EDUCATION

Identified by Rex Meyer at the international congress on the improvement of biology teaching, Uppsala, 1975

- most training programmes developed in the last five years have tended to focus on the development of professional competence rather than merely on the training in understanding of concepts or in academic pedagogy (competency-based programmes)
 - trends in the new curricula which reflect the needs of society have resulted in a rethinking of the roles of the science teacher and of his desirable attributes. They have contributed to a re-organization of the objectives, patterns, content and processes of his pre-service and in-service training
 - with respect to the content of courses, there is a trend to make it more relevant to personal, social and national needs
1. training in understanding objectives changes to training in writing objectives generally expressed in behavioural terms
 2. diversification of conventional forms of practice teaching to make more effective use of time and to include more vicarious experience: films, audio recordings, microteaching and video-replay
 3. an appreciation of student differences leads to linking instructional techniques to individuals and groups, by matching resources and strategies with needs of individuals, e.g. audio-tutorials, programmed instruction and multi-media training kits

4. the excursion or field trip evolves into training programmes for environmental and community analysis
5. conventional block timetabling leads towards minicourses and other flexible ways of using time
6. small group work evolves into a study of interpersonal relations and leads to sensitivity training
7. classroom observation develops into interaction studies
8. the *Teachers Guide* evolves into special pre-service and in-service training modules for new curricula
9. simpler aspects of role playing develop into more sophisticated forms of educational games and other simulations
10. group co-operation moves towards team-teaching and team-training
11. laboratory and classroom organization and strategies evolve into techniques of openplan education
12. project work evolves into genuine research study
13. assessment by formal examination changes to assessment of the formative development of specific teaching skills and of more general teaching competencies
14. stress on cognitive aspects of teaching changes to training for attitudinal development with special reference to their application to social problems
15. inquiry and problem solving emphasis enlarges its perspective to include training for creativity and divergent thinking
16. analyses of given courses of study changes to development of skills of curriculum construction
17. learning to use resources widens its scope to include training in the production of resources
18. conventional training in communication skills changes to training in making full use of the techniques of educational technology
19. training for organization of classroom and laboratory resources changes to techniques of utilizing facilities of the media resource centres and services of the school and of the district
20. training in assessment of teaching moves towards evaluation of in-service and pre-service training programmes.

NECESSARY SKILLS AND ATTITUDES OF A SCIENTIST

Identified by the European Communities Biologists Association at workshop in Amsterdam, 1976

A. Basic skills

Necessary skills of a biologist

- The use of classical and advanced instrumental techniques.
- Experimental skills (planning, performing and evaluating experiments).
- Mathematical skills (use of statistical techniques for collecting, evaluating and presenting biological data, special forms of diagrams and logarithmic scales).
- Verbal and reporting skills (discussion techniques, lecture techniques, techniques of writing scientific texts).
- Bibliographical techniques (reading techniques, use of libraries).
- Observation techniques (intellectual skill towards separation of syntactic and semantic aspects)

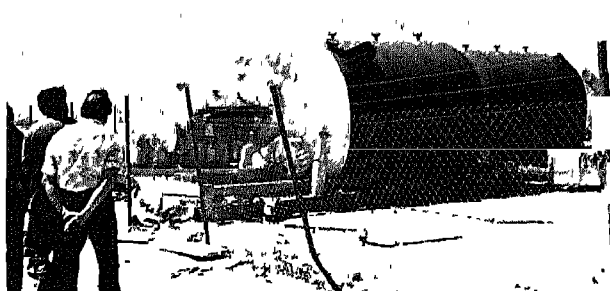
of data i.e. of sensory experience and interpretation).

- Hypothesis techniques (the technique of solving a problem by forming hypotheses that can be tested by empirical data).
- Methodical skills in science (at least the clear distinction of causal explanation/teleological explanation, deductive/inductive thinking, linear causal thinking/complex thinking in causal networks).

B. Basic attitudes

Necessary attitudes of a biologist

- Tendency towards empirical proof on data ('empirical basic attitude').
- Readiness to test formal theories for use in biology (e.g. theoretical physics, theoretical chemistry, mathematics, general systems theory or philosophy of science).
- Awareness that biology is not an 'easy subject', but on the contrary needs a particular standard of training in complex thinking and of wide-ranging knowledge in different fields.
- Openness to new aspects of biology (openness for innovations in the biological sciences and for continuous learning and re-learning).
- General cautiousness in changing biological systems.
- Openness for co-operation, teamwork and interregional (also international) exchange.



Teachers have to learn so much!

RESOURCES AND RETRAINING

Cheong Siew Yoong

Throughout the world there is a great deal of innovation in the development of resources for the education of science teachers. This seems to be a response to, on the one hand, the application of technology to the field of science education and, on the other, to the changing philosophy and methodology of school science teaching, bringing a wide array of materials for the use of pupils and teachers. Teachers must now play different rôles, and the new school materials are giving them opportunities to put into practice the principles of their training. Van der Cingel, in this book, deals in particular with the needs of teachers; this section considers innovations in the context of resources, and trends, but there are many issues in this important field that must be dealt with more fully elsewhere.

THE CONTRIBUTION OF RESOURCES TO TEACHER EDUCATION

That there is a close relationship between a particular methodology of instruction and the instructional goals cannot be sufficiently emphasized. For instance, the emphasis on process skills might make the lecture unsuitable as a method. When a given resource is used in a way different from what was visualized by the developers, the outcomes will be different. For example, the materials of the Science Teacher Education Project (STEP) in the United Kingdom have been designed for small group interaction, and if they are used otherwise, the objectives are unlikely to be achieved. Means can therefore not be divorced from process, context and goals. The materials of STEP and ASTEP (Australia), microteaching, protocol materials, multi-media modules, auto-tutorial learning, and minicourses, are effective only in the context of the purposes and methods for which they are designed.

It might be useful to attempt a task description of innovations in resources: to develop learning environments that exemplify changed classroom methodologies; to direct student-teachers towards more active and inquiry-oriented learning in their pupils; to establish optimum conditions for interaction between student-teachers and tutors, between student-teachers and materials, and among student-teachers; and to create aspects of real-life situations for study and analysis by student-teachers. Within this framework, knowledge, skills, values and attitudes required for teaching integrated science are acquired, enriched and transferred.

RETRAINING IN SOUTH-EAST ASIA

The state of progressiveness in integrated science teacher education varies widely round the world, and the priorities and constraints are unique to each country, so that in the space available here it is not possible to provide a comprehensive review. This treatment, therefore, confines itself to a brief and selective account of strategies that have been used in the developing countries of South-East Asia.

A dominant need is the retraining of all teachers for the integration of science teaching. A large population of science teachers has to be retrained as quickly as possible, if curriculum change in schools is to be rapid, and the problem is compounded when the geographical area is wide and many of the teachers are in rural schools. To deal with these problems, two complementary strategies have been used, the decentralization of training and 'distant' teaching.

In decentralized training, the training is provided at the teachers' places of work rather than at national and regional centres. Mobile training is used in Malaysia and the Philippines. In India, Malaysia and Nepal, training programmes are organized near the place of assignment. Local schools and teachers' centres are used in the Philippines and Thailand.

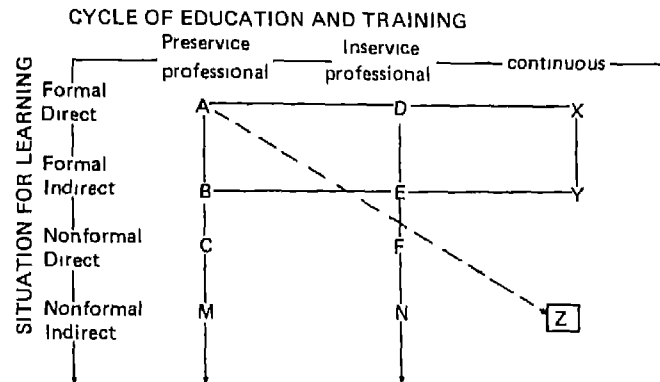
The use of 'master teachers' has been formalized into the national systems of in-service training to alleviate shortage of teacher trainers. School supervisors are used in Indonesia and Sri Lanka, and other key personnel are used in Japan, Malaysia and Thailand. Training of these takes place in central institutions, and they in turn train other teachers in various localities at primary and secondary school bases which also serve as resource centres. Harlen in her chapter discusses this strategy. It is not without problems. Like a water ripple, the multiplier effect gets weaker with time and distance, the criteria for selection of the key personnel are not always appropriate for the task they are to perform, and the facilities in remote schools may be inadequate. The effectiveness of the master teachers is very much dependent on the quality of the training they receive.

Distant teaching is the kind that is provided by the Open University and by educational television and radio programmes. This procedure is increasingly used in developing countries to upgrade teachers in certain professional skills on a continuous basis, not so much for *ad hoc* in-service training for specific courses. The Centre for Educational Technology in India has developed a multi-media package for the reorientation for science of 1.7 million primary school teachers, using radio and television, activity guides, enrichment materials and tutorials. In Malaysia, the Ministry of Education uses educational television towards a number of objectives including the teaching of science, assistance in teacher-training programmes (pre-service and in-service), and informing parents and teachers about innovations. Sri Lanka has a correspondence teacher education programme for both untrained non-specialist teachers and graduate teachers working towards a higher diploma in education.

TRENDS IN SCIENCE TEACHER EDUCATION

The most pervasive change has been in the training methods towards small group and, to a lesser extent, individualized learning. Microteaching, minicourses, audio-tutorial systems and protocol materials are among those in use, but highly technical and technological procedures do not meet problems in the developing world. More feasible in these countries is simulation and role playing. Realistic games, representing model situations of the real teaching world, provide student-teachers with opportunities to solve problems and make decisions without jeopardizing children's learning. The students see relevance in their training, and learn to put theory into practice. Countries lacking technological sophistication may still apply principles of interaction and communication in human-based techniques of small group discussions, seminars and direct classroom observation. These complement laboratory-based activities and use of resources in an approach not unlike that of STEP.

There has been a clear trend towards viewing teacher education as a lifelong process, the formal institutional training serving only to initiate the teacher. This raises the question of the nature and requirements of each phase. The various phases, and the alternative approaches in each phase, are shown in Figure 1. The vertical arrows indicate the direction in which resource development appears to be moving. In terms of providing opportunities and facilities for the training of science teachers, I believe we have achieved much at levels A, B, D, E, X, Y and, to a lesser extent, at levels C and F. We should now be prepared to spend more funds and effort in developing resources for the other levels. In fact, in years to come there should be a gradual move to produce the types of materials that would enable us to progress towards the direction of Z for the purposeful attainment of the objectives of lifelong education of science teachers in general and integrated science teachers in particular.

Figure 1 Resource needs

Operational definitions: The term formal refers to certificate granting and institution-based. Direct is operationally defined as tutor directed and controlled while indirect is self-initiated or group effort which is not tutor directed

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See also [13, 169, 305, 325].

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TYPES OF EVALUATION

Evaluation activities of educational programmes in most of the third world countries, especially in Africa, have followed what has been described as 'conventional wisdom', a practice which associates truth with convenience and the good with the familiar and comfortable. Although conventional wisdom is said to imply a lack of logical rational thought in arriving at a course of action and might seem to imply a lack of evaluation, it does, in fact, involve a kind of evaluation - non-systematic, non-rational weighing of alternatives and the selection of the traditional rather than the divergent course of action.

Educational programmes are of many kinds, varying in scope, size, duration, clarity and specificity of programme input. These differences in programmes have important consequences for the type of evaluation that is feasible and productive.

In discussing the evaluation of educational curriculum, Scriven [437] broadly distinguishes between formative and summative evaluation. Formative evaluation produces information that is fed back during the development of a curriculum to help improve it. It serves the needs of developers. Summative evaluation is done after the curriculum is finished. It provides information about effectiveness to school decision makers who are considering adopting it.

The widely used model of the curriculum (Figure 1) shows that evaluation (formative evaluation

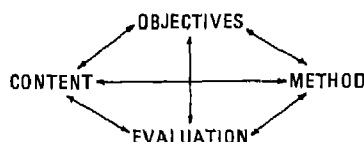


Figure 1 Model of curriculum

in Scriven's classification) is a vital component of the curriculum, especially perhaps for developing countries. While integrated science has been firmly established in some of the developed countries, its concepts and principles are just beginning to be accepted in a number of the third world countries. The integrated science programmes in these third world countries are relatively young and so demand gentle and sympathetic type of evaluation. The emphasis on formative evaluation is vital especially as a too rigorous summative type of evaluation might strangle this new educational trend in science which is fast spreading. Whatever type of evaluation is however finally adopted for integrated science education, it should take into serious consideration the environmental problems of the society, the politics and the resources, both human and material.

PURPOSES OF INTEGRATED SCIENCE EVALUATION

Where there is an existing educational programme, it is often necessary to carry out a summative evaluation to facilitate decisions about whether to continue or discontinue the programme, improve procedures adopted in the programme, add or drop specific programme strategies and techniques, institute similar programmes elsewhere, allocate resources among competing programmes and accept or reject a programme theory.

The existing programme in the recent past has generally been of the general science type. One purpose, therefore, of evaluating an integrated science programme is to compare the gains (pay-off)

of adopting the programme with those of other programmes similar in a number of respects. For instance, a comparative study of integrated science and general science may provide information which can lead to a decision on the allocation of resources between the two programmes or even to the abolition of one in favour of the other.

A second purpose of evaluation would be to measure the effects of a given programme against the goals it sets out to accomplish, in an effort to contribute to subsequent decision making about the programme. For example, in 1970 when integrated science in Nigeria was established, the first issue of the *Curriculum Development Newsletter* (published by STAN) spelt out a set of skills and other aims visualized for the forthcoming programme. There are two implications here for integrated science as a curriculum programme. In the first place, a goal evaluation of an integrated science programme will seek to clarify and assess the worth of the goals against some explicit criteria within the social environment of the programme. In the second place, a goal evaluation of an integrated science programme might seek to assess the effect of the programme on the users, in this case students and teachers, to find out if the goals claimed by the programme have been attained. In this case, the criteria used will be largely implicit in the programme. Information obtained from such goal evaluation may lead to the following decisions: to continue or discontinue the programme, to accept or reject the programme theory and to institute similar programmes in other places with similar environments.

A third purpose of evaluating an integrated science education programme is to strengthen the programme. This could be in the direction of materials (textbooks, equipment) evaluation. An integrated science programme might have been introduced into a school system without thorough consultation with the teachers. Problems arise as to the suitability of the text materials and so an evaluation becomes necessary before decisions can be objectively taken about the materials. In most developing countries, a materials evaluation would seek not only to identify the problems with use of the materials but also to make suggestions about their improvement. To a large extent, this kind of evaluation is formative in character. Information obtained from such materials evaluation may lead to the following decisions: to improve procedures adopted in the programme and to add or drop specific programme strategies and techniques.

A distinction between programme evaluation and evaluation research has been made by many scholars, notably by Weiss [450, p. 5-9], Cooley and Lohnes [375]. The point therefore arises whether integrated science education programmes can be subjected to *evaluation research*. Since evaluation at whatever stage has been defined as a process by which relevant data are collected and transformed into information for decision making and since both programme evaluation and evaluation research contain the elements of evaluation, Coleman argues that the distinction should really be between 'disciplinary research', i.e. research designed to advance knowledge in a particular way and 'policy research', i.e. research which is designed to affect policy decisions. Cronbach and Suppes [379] made a similar distinction, using the terms 'conclusion-oriented research' and 'decision-oriented research' respectively. It can be argued, I imagine, that any integrated science programme which has been firmly established for more than a decade for instance should lend itself to decision-oriented research. The problem for research may not be explicitly stated in the objectives of the integrated science programme themselves but might be implied. Coleman has identified two main characteristics of policy research. One is that the research problem originates outside the discipline in the 'world of action', and the other is that the results of that research are destined for the world of action. He then went on to identify properties of the world of action which he felt were relevant to policy research. These properties are concerned with the time constraint imposed by the world of action, the different use of language and concepts, different interests, and ways of controlling resources.

The point that should be stressed about integrated science programme evaluation is the fact that evaluation research can play a useful part in strengthening the programme but, if not properly timed, evaluation research can cripple the programme. Of significant note is the fact that integrated science programmes in most developing countries are just taking off. These programmes must be given time to mature and to grow before subjecting them to any form of research. Curriculum designers and developers have always made this point clear and it would seem that one bone of contention between them and researchers stems from this rush on the part of researchers

to 'pry into what is still being developed'. So while it is desirable to research into integrated science programmes, it is of importance to so time the research as to produce a multiplying effect.

STAGES AND STRATEGIES FOR INTEGRATED SCIENCE EVALUATION

The development of a curriculum project is a process that requires a relatively long time. Throughout the process of any curriculum development and implementation, a great variety of problems and questions arises. In order to cope with this multitude of problems, many evaluation sub-studies may be undertaken. The problems with which evaluation is supposed to deal will vary according to the stage of programme development and utilization. Accordingly, evaluation methods and strategies will differ also.

At each stage, particular types of evaluation are needed to support the successful development and use of the new programme. Lewey [405] discussed six stages of curriculum development along with the necessary evaluation applicable to integrated science evaluation. These are shown in Table 1. It was clear from the working group discussions that the model would be applicable

Table 1. Six stages of curriculum development

Stage	Roles of development	Roles of evaluation
Determination of general aims	Decision about - general aims - school structure	Studies on - expected changes - cultural values - social forces - present level of achievement - feasibility of programme
Planning	Writing outlines Preparing instructional material	Examining adequacy of objectives, content, strategies, judgement of material
Tryout	Monitoring teaching in tryout classes Modifying material	Collect evidence through observation, judgement, discussion with teachers, students Student products
Field Trial	Slightly modify the programme Determine optimal conditions of programme use	Select sample Collect evidence about the efficiency of programme under various conditions
Implementation	Links with supervisors, examination system, teacher training	Examining final form Evidence on efficiency of system links Evidence of efficiency of teacher training.
Quality Control	Implement Recommendation Plan 'second generation' programme.	Examining quality of implementation Studying reasons for changes in efficiency Suggesting remedies if needed.

to the systematic formative evaluation of integrated science materials. Also there was consensus with the views expressed by Lewey that the evaluation of a particular educational programme is not performed through a single study. At various stages of programme development, alternative

pathways of action may appear, or doubts may arise concerning the merits of some parts of the programme. In such cases, an evaluator may be asked to define a problem area precisely to collect appropriate data and to summarize them in a way that may help decision making. The sub-study evaluation approach was highly recommended for integrated science. There is real advantage, it was claimed, in evaluating an integrated science programme from numerous points of view and in gathering information about its merits and faults as perceived by different persons.

There is need however to consider the relative merits and demerits of internal and external evaluations of integrated science programmes. The point was made that in order to guarantee a fair appraisal during the formative period of the programme, the evaluator should as much as possible be part of the programme, i.e. an internal evaluator. However during a summative evaluation stage, the evaluation should be entirely independent of the programme, i.e. it should be conducted by an external evaluator. Whoever carries out an evaluation, insider or outsider, the major point to bear in mind is that the objective nature of evaluation must be evidenced; the evaluator should thus be regarded as a *critical friend*.

EVALUATION OF OUTCOMES IN INTEGRATED SCIENCE EDUCATION

At this point, we need to make a distinction between the evaluation of integrated science programmes at the developmental stage and evaluation of outcomes. In the latter case, one examines the effect of integrated science on students, teachers, school administrators and parents. Has the exposure to integrated science affected, for instance, the attitude of students to science? Do students who are not exposed to integrated science demonstrate significantly different attitudes (positive or negative) to science? What about the science teachers - do they see the introduction and teaching of integrated science as a breakthrough in their careers as science teachers? Would the teachers have behaved differently if they had taught general science instead of integrated science? Or do teachers feel that integrated science has created more problems, academic and administrative, for them in the school systems? What about the environment? Has integrated science triggered off new thinking about use and conservation of the environment? These and many other questions about outcomes should be asked about integrated science. Answers to these questions are needed especially in developing countries where integrated science has come to be the new approach to science teaching, especially at the primary and lower stages of secondary school education. Investigations leading to massive evaluations must be systematically and vigorously pursued by science educators, professional evaluators and curriculum designers in order to provide the evidence which should be the basis of decision making by administrators and politicians.

Before passing judgement on (evaluating) the effects of integrated science education (has it succeeded as a way of learning science or not?), I should like to draw attention to the basic question raised by Yoloye [348], referring to the African Primary Science Programme (APSP).

Should it [criteria of success] be the quality of the materials, the degree of adoption of the materials or the quality of people produced by the programme?

He then went on to say that in the course of APSP evaluation, it became clear that the crucial criterion for assessing the success or otherwise of APSP cannot be merely 'whether or not the materials work in the African classroom' but more important 'whether or not APSP has contributed significantly to the production of a core of people, within Africa, with experience, expertise and a mental orientation geared towards continuous curriculum renewal'. We can now, I imagine, ask a similar question by substituting integrated science for APSP. I now know that integrated science popularized by Unesco and by the Scottish Education Department can claim a large measure of success in effecting positive change not only in Africa but the world over.

There has been significant work on the evaluation of outcomes of integrated science. Sally Brown [39, 42] has provided some evidence about the effect of integrated science education on both students and teachers. In the United Kingdom, in the West Indies, in Brazil, in Malaysia, in Japan, in Ghana, in Nigeria, for example, scientific evidence is being assembled to justify

the popularization of integrated science as a fast growing science discipline. With this considerable amount of work going on in the evaluation of integrated science education, it sounds superfluous to make a plea that more investigations are needed, especially in the regions of the world where the idea of integrated science is only just being hatched. The experiences of researchers might be invaluable here in providing a *modus operandi* in the evaluation of integrated science education, particularly the outcomes.

PROBLEMS OF PAST AND CURRENT EVALUATION EXERCISES

Having argued for the evaluation of integrated science programmes, we must now face the problems.

1. Man-Power

Professional evaluators are not available in many countries in reasonable numbers. If educational evaluations are to be thoroughly executed, we need people who to a large extent understand the logistics of evaluation. Because of the lack of professionally-trained evaluators, a number of the evaluations in education, in general and integrated science in particular, have been undertaken by a small number of available evaluators. This restricts the amount of work that can be accomplished, but in some countries the few evaluators have embarked on crash training of classroom teachers, Ministry of Education officials, school administrators and even university students to assist in evaluation exercises.

2. Finance

The provision of financial support for the evaluation aspects of educational programmes has not been generous enough to fill the need. In most school systems, the evaluation of programmes is low in priority, largely because programmes are initiated and supported without any demand for evaluation evidence. The social and political considerations outweigh any others in decisions about educational programmes. Where funds are provided for evaluation, they are, more often than not, insufficient. An evaluator who decides to embark on a national study will have to spread his resources thinly.

However, with programmes that are supported with funds from agencies and foundations, ample provision is now being made for the evaluation of such programmes. Unfortunately, most of such funds come in to provide support more for summative evaluation than for formative evaluation. And usually at the termination of the programme support, little or no funds are available to carry out further investigations on a long-term basis. Longitudinal studies of outcomes of programmes have of necessity been reduced to a minimum. Limitations of funding for carrying out extensive evaluation, and an attempt at solution, were mentioned in the evaluation report of Caribbean integrated science by Reay [260].

3. Curriculum Developers Versus Evaluators

In the history of evaluation, the world over, the element of 'threat' is always present during an evaluation exercise. Curriculum developers may see an outside evaluator as an intruder who, they claim, 'cannot see the problems we face from the proper point of view'. As a result, they may resist any attempt to inject an outside evaluator into their programme and if, notwithstanding, an evaluator is brought into the project, the curriculum developers may create several problems for the evaluator. This may be a 'natural defence mechanism' of curriculum developers, but evaluators are sometimes welcome to a programme.

In a number of the integrated science evaluation exercises [61] there seems to have been a considerable amount of formative evaluation in which the evaluator was brought in as part of the programme or in which the curriculum developers themselves acted as evaluators. In either case, significant information has been obtained.

4. Teachers' Interest

Evaluation of integrated science education involves teachers and pupils in schools. In some cases, the job of an evaluator has been made very difficult by the classroom teacher who sees the evaluator as an intruder who this time has come to disturb his lessons with his research work. In such circumstances, the teachers do not see themselves as part of the exercise. Some teachers have complained that they never see the reports of such evaluative studies - they claim that all that is important to the evaluator is the collection of data to help him publish articles in journals that they, the teachers, do not see or read. In such situations, evaluation of pupil and teacher attitude to the subject has been made difficult.

A way out of this has been the designation of certain schools as 'project schools' and, surprisingly, this works well - both the teachers and pupils see themselves as privileged, and so the evaluator's job is made easier. It has also been found that good interpersonal relationships between evaluator and classroom teachers lead to considerable co-operation.

5. High Mobility Of Teachers And Pupils

For most evaluation exercises, much time is necessary to follow a study through to its conclusion. And where a study has been started with certain teachers and pupils as a sample, it is usually expected that these teachers and pupils will be available during the life of the study. Unfortunately, in certain cases, studies have to be abandoned when teachers or pupils have moved out of the particular school. Anyone who is familiar with situations in parts of Africa knows that high mobility of staff is common. One therefore tends to undertake studies which last for short periods.

CONCLUSIONS

Whichever way we look at it, objective evaluation is an essential precursor to informed decision making in the developed and developing countries. The unique position of integrated science as an acceptable way of teaching science to young people can no longer be debated. What is not always recognized is the need to improve on our evaluation strategies so that we can improve on the type and level of decisions taken about integrated science.

Decisions will have to be taken at various stages.

1. Decisions will have to be taken on whether to adopt an integrated science approach to science teaching or not. Such a decision should be based on a thorough knowledge of what is actually meant by integration in science. The decision maker at this stage is more often than not the educational administrator in a school system. A decision of this nature is a policy decision; it will affect many other decisions, like finding teachers and laboratory facilities.

2. Decisions will have to be taken on how to make the teaching of integrated science *effective* in the school system. This kind of decision will be based on the general academic background of teachers in the school system. This again can be a policy decision as it might involve the administration in providing opportunities for pre-service and in-service teacher training.

3. Decisions will have to be taken on which integrated science textbook and teaching materials are most suited to a locality. This decision can be taken judiciously only if information on materials evaluation is available. It is most likely that the classroom science teacher and not the administrator is the best qualified person to take this decision since it is the classroom teacher who will be using the materials.

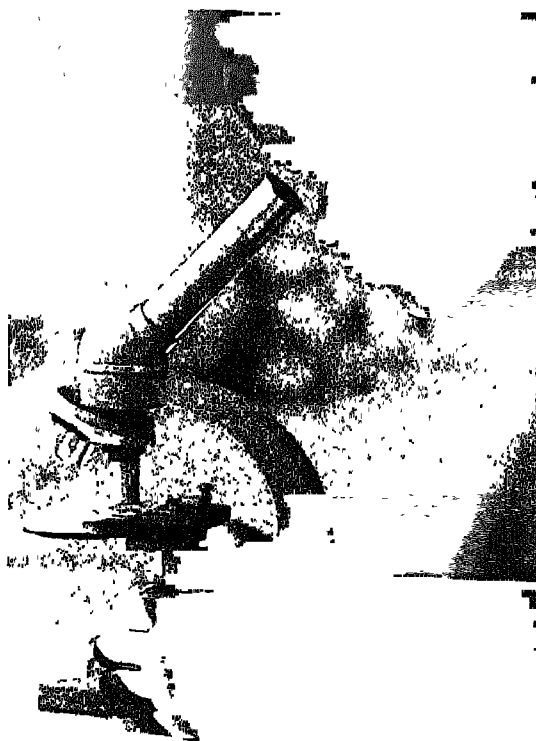
4. Decisions will have to be taken on how far in the school system integrated science teaching should go. Integrated science at the primary stage of schooling is not generally disputed; it is what happens after the lower secondary stage that is open to debate. A decision on whether to carry integration right through secondary schooling will have to be taken by both administrator and the classroom teacher. While it is one thing for the administrator to provide the infrastructure for teaching integrated science, the personal decision of the teacher must count. If

teachers do not *feel confident* that they can teach integrated science up to GCE Ordinary Level, for instance, success is unlikely.

5. Decisions will have to be taken on how best to sustain the interest of the pupils for which the programme has been developed. This decision will have to be taken by the classroom teacher based on his personal experience with the pupils he teaches. This decision is of vital importance to integrated science programmes because if science is presented to beginners as difficult or uninteresting, with little relevance to future academic plans, there will most likely be a shortage of science-oriented students at the higher academic level and in general of scientifically educated people.

Four major groups of people play important and significant roles in evaluation. These are (i) the administrators and policy makers, (ii) the evaluators, (iii) the curriculum developers and (iv) the users. There are certain essentials for viable relationships among the four groups of people. There must be *tolerance* on all sides. While it is not always possible to accept all the views put forward by one's co-workers, it is important to criticize the views *constructively*, so to say, there must be *understanding* of both the project objectives and of oneself. Finally and perhaps most important, is the fact that there must be an easy and efficient means of *communication* between all members of the groups. No serious problems should arise when the evaluator operates in such a way as to demonstrate a sense of belonging to a curriculum project.

Clearly, this chapter has not attempted to provide a recipe for evaluation. What it has attempted has been to provide suggestions which, from the collective experience of the working group, should be borne in mind by all participants in the curriculum innovation process. Compared to the exciting and creative work of writing the curriculum, evaluation can be tedious and its results are often sobering, perhaps disappointing. Without evaluation evidence, however, as we scientists should be the first to recognize, curriculum development and implementation must be intuitive and difficult to justify. Even scientists, though, need to remember that they are dealing with people, and clumsy evaluation can do more harm than good in our attempts to give children better teaching in science.



How do we know if they are learning?

14. Environment as an integrating factor in science education

Rais Ahmed

Abstract of plenary paper

Education is a basic social and human need. Without it, or with inadequate education, national development is inconceivable. Therefore the nature and quality of science education can be judged only with reference to its role in enabling education to fulfil personal and social aspirations.

In the developing countries particularly, the greatest historic failure of education has been that its approach, structure, content and methodology have ensured restriction of education to the relatively privileged, and have been a factor in causing massive adult illiteracy on the one hand and unemployment of the educated on the other. If society is to be saved from running downhill and perpetuating an unjust social order and if the quality of life in our countries is to be transformed, a far reaching educational change is imperative.

The most important aspect of the change is that education should cease to be far removed from the problems of daily life; it should stop being based on the consideration of building up knowledge for later studies in each discipline; it should give up its pretence of being more theoretical than practical - of being preparatory for white collar jobs rather than jobs in general and self-employment. It must be designed to introduce the child to the real world of phenomena in which we interact with natural and man-made surroundings and struggle to make a living. It must impart mental and manual skills needed to gradually change the environment. It is believed that an education of this kind will be more useful and productive and hence attractive for the common peasant or worker in our countries.

This kind of education will be as comprehensive as the reality itself; science and technology will be a harmonious component of such an education just as history or geography will be others, and they will appear not as separate entities but as intrinsic elements of each aspect of the reality. The study of a tree or a lake will encompass not only the physics, chemistry or biology of it but also what their rôle is in providing us food or medicine. The trees or lakes will be studied concretely for their rôle in local history, economy and environment. Even the dignity and beauty which they lend to our surroundings will be appreciated, be it in painting or poetry. The study will be followed by action, if it is called for, in protecting one, cleaning the other or utilizing their product - bringing us back to science and technology.

It is our contention that such an education will be based on the more directly observed and experienced; there will be a synthesis of theory and practice; it will be based on imagination, resourcefulness and creativity, it will highlight our knowledge as well as our ignorance, our success as well as our failure in utilizing our resources. Thus environment will be a natural integrating factor not only for science education but for all learning directed towards social change. Higher and diversified levels of education would also be attained better when the foundation is so firm and unified.

The full text of this paper (12 pages) is available from the author.

15. Future developments in integrated science education in relation to environmental education

Hubert Dyasi

An enthusiastic schoolteacher once presented a science curriculum development centre with notes of her class activities during her students' study of the mosquito. The record showed that the students had gathered data on where mosquitoes are found, at what times of the day they seem most active, their breeding places, and on characteristics of the different stages of their life history. They also studied techniques of making population estimates in nearby swamps, and of controlling mosquito populations. As a result of their understanding of the habitats, behaviours and general characteristics of the various stages in the life history of the mosquito as well as of the association of mosquitoes with malaria and the need to control the spread of malaria by limiting the mosquito population, the students had decided to form a children's society for the eradication of malaria. The society would educate the community about likely breeding places, estimation of populations of mosquito larvae, and about the effects of using certain kinds of chemical sprays on the environment.

These activities were carried out during integrated science education lessons. But it may be asked whether they could be of any special value to environmental education. The broader question is what special contributions can integrated science education make to the furtherance of environmental education?

THE NATURE OF INTEGRATED SCIENCE AND OF ENVIRONMENTAL EDUCATION

Science, of which integrated science is but one level, is usually associated 'with man's natural desire to know, to understand, to explain, to predict, etc.' [271, p. 2]. Questions relating to its process would tend to be of the 'what is' and 'how is' variety. In science, the motivation appears to be curiosity about or need to understand better some phenomena - natural or man-made, and the process of trying to find out about, or understand, those phenomena is scientific research. The products of scientific activity are the increment to our organized body of knowledge.

In the course of its development, science has grown into specialized branches. Yet there is inherent unity in all of science - a special way of knowing, for example. Integrated science education seeks to highlight that unity. Integrated science also incorporates applied science whereby an organized body of knowledge is brought to bear in solving practical problems.

Also inherent in integrated science education are attitudes and values associated with open-mindedness, constructive scepticism, and the probabilistic nature of scientific knowledge. What is often not realized is that integrated science education can incorporate questions of propriety in the use of scientific knowledge, a matter discussed in more detail by Lewis in his chapter.

Environmental education, as described currently, employs the science of ecology as baseline knowledge to promote understanding of the total environment. Because the environment is the basis of integration (and, as Ahmed points out elsewhere in this book, the environment consists of natural, man-made, and social and aesthetic components), environmental education tends to be all-embracing and incorporates aspects of knowledge which fall outside the purview of integrated science education. It seeks to present a holistic and balanced view of the world [324, p. 32].

In the study of the mosquito reported above, the students collected data using scientific approaches such as observation, hypothesizing and inferring. There were also issues of problem-solving, e.g. what to do to reduce the mosquito population and how it should be done. The formation of a malaria eradication society arose out of attempts to solve that problem. The path to the decision to form a society must have included a consideration of whether it was appropriate for young people to try to influence the community directly. But once the decision was made, action (formation of the society and its involvement in the community) followed. This process would seem to contribute immensely to a scientific understanding of a (significant) portion of one's environment. Although it could be argued that individual sciences contribute useful knowledge, the integrating nature of integrated science education would contribute more significantly because environmental education aims for a balanced and holistic view of one's environment. Selim in this book reports the decision of the Arab States to use the environment as the integrating strategy for curriculum development.

GOALS OF ENVIRONMENTAL EDUCATION

The goals of integrated science education discussed in the chapters by Booth, Showalter, Gadsden and co-workers, and Haggis and Adey have shown a trend towards, amongst other things, attention to the learners' social and cultural perspectives and to the imperatives of their environment, concerns dealt with forcefully by Ahmed in his plenary paper for the Conference.

The trends give us a perspective for the goals of environmental education enunciated at the 1977 Intergovernmental Conference on Environmental Education held in Tbilisi: to foster clear awareness of, and concern about, economic, social, political and ecological interdependence in urban and rural areas; to provide every person with opportunities to acquire the knowledge, values, attitudes, commitment and skills needed to protect and improve the environment; to create new patterns of behaviour of individuals, groups, and society as a whole towards the environment.

The goals have been spelled out in terms of objectives under five categories: *awareness* - to help social groups and individuals acquire an awareness and sensitivity to the total environment and its allied problems; *knowledge* - to help social groups and individuals gain a variety of experience in, and acquire a basic understanding of, the environment and its associated problems, *attitudes* - to help social groups and individuals acquire a set of values and feelings of concern for the environment and the motivation for actively participating in environmental improvement and protection; *skills* - to help social groups and individuals acquire the skills for identifying and solving environmental problems; and *participation* - to provide social groups and individuals with an opportunity to be actively involved at all levels in working towards resolution of environmental problems [444].

In view of these goals and objectives, it is apparent once again that integrated science education can make a special contribution towards environmental education. Integrated science portrays the scientific aspects of viewing one's environment, and these are basic to understanding. With that understanding, individuals become aware of the needs and problems in the environment. Meanwhile, research into integrated science education can contribute immensely by providing knowledge of the learner; studies of his intellectual, affective and other attributes can be used by developers of environmental education curricula in making decisions about content, problem-solving activities, values and attitudes.

GUIDING PRINCIPLES OF INTEGRATED SCIENCE AND ENVIRONMENTAL EDUCATION

Some integrated science education projects followed closely Piaget's developmental model. Additional important educational principles include an emphasis on participatory learning rather than on teaching, use of problem-solving approaches and of materials that are of immediate interest and relevance to the learner. Also, in the 1970s integrated science education projects began to emphasize themes that have social significance, themes such as energy, technology and development, an issue dealt with much more fully by Lewis in his chapter.

The basic principles of environmental education are contained in the Tbilisi Declaration which stresses, *inter alia*, the total nature of the environment, an interdisciplinary approach, lifelong education, values clarification, as well as learner participation in problem-solving.

THE CONTENT OF INTEGRATED SCIENCE AND OF ENVIRONMENTAL EDUCATION

Elsewhere in this book, the content of integrated science education in general education is discussed at length. The content is usually presented in an integrated fashion through the adoption of themes such as the nature of matter, energy and its transformations, ecology, nature and properties of living things and others. In addition to these themes, several integrated science projects include studies of water, including pollution, petroleum, cultural heritage, and shelter (e.g., the Australian Science Education Project); the atmosphere, landforms, economics, aesthetics, ethics, and the built environment (e.g. some projects in the United Kingdom); biological, agrotechnical, cultural, economic, and social aspects of agriculture (e.g., Agriculture as Environmental Science in Israel); man and his surrounding environment, man and natural resources, man and universe (e.g. ALECSO project in the Middle East).

Since an ecological, and therefore a scientific, base is adopted in environmental education, some of the content would bear close resemblance to that of integrated science. But, as Capurro commented in his submitted paper, ecology is only one science and might not be as broad as integrated science.

In 1971 the International Council for the Conservation of Nature and of Natural Resources (IUCN) suggested an environmental education curriculum which would include the following concept groups: the physical environment - planet earth, energy flow, atmosphere, climate and meteorology, lithosphere, landforms and soils, surface water, ocean; living things - general ecology, populations and behaviour; and human activities - social organizations, production systems, economics, cultural, historical and aesthetic conditions, controls and planning [401].

And one of the most comprehensive models of an environmental education content has been developed by Stapp, who outlined environmental concepts and understandings by grade levels [440, p. 12 - 13]. Under the concept of the ecosystem, for example, would be included its composition and nature, energy, and pollution.

Stapp suggested other areas such as population, environmental decision, and environmental ethics. There are numerous other concepts suggested by different individuals and groups. Perhaps the most important sources of information in this aspect are the documents submitted to Unesco by the countries participating at the Tbilisi Conference.

Whether environmental education is a discipline or school subject in its own right is a matter of debate. As has been shown above, in some places it is regarded as such, but in others (as among the participants of the Nijmegen Conference) it is viewed as a dimension or perspective of general education and not as a separate area of the curriculum.

LEARNING METHODOLOGIES OF INTEGRATED SCIENCE AND ENVIRONMENTAL EDUCATION

Similarities between integrated science and environmental education are very apparent in the learning methodologies they adopt as well as in the instructional resources they utilize. For example, there is extensive use of activity methods, descriptive and analytical systems, informal and experimental situations, and two-way communication methods [340]. Learning techniques include the use of measurement and monitoring (sampling techniques, quantitative measurements and recording of data, monitoring of daily and seasonal changes, examination of relationships among variables) field trips (for studies of animal behaviour, soil and vegetation, lakes, streams and estuaries, patterns of land use, and for development of sensitivity to different environments); outdoor areas such as botanical and zoological gardens, agricultural and industrial areas, museums, and nature trails, mapping e.g. pictorial representation of concepts and graphs.

It may be argued convincingly that the above-mentioned methodologies and resources are not the monopoly of integrated science and environmental education. That argument would hold except that these two areas of study include interfaces between natural systems and human activities i.e. the effects of people's decisions on the natural systems and vice versa. The main ingredient is the sense of coming face-to-face with reality that is fresh, 'the freshness of which holds and sustains emotions'. [393]. If it is continual, the confrontation with this kind of reality would hopefully harmonize the scientific way of life and thought with our best feelings and thoughts.

AN EMERGING RELATIONSHIP

At the Nijmegen Conference the perceived relationship of integrated science education and environmental education was represented diagrammatically as in Figure 1*. As the diagram shows,

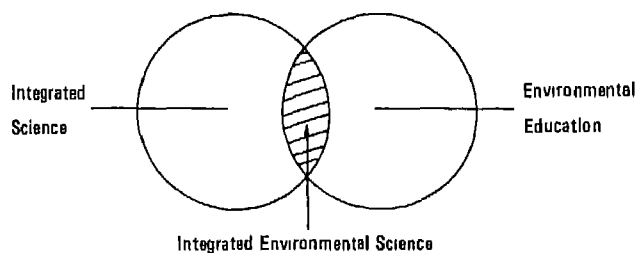


Figure 1. Relationship of integrated science to environmental education

there are aspects of integrated science which are not of particular relevance to environmental education. Indeed, there are integrated science programmes which confine themselves to the 'unity of science', and these programmes differ significantly from environmental education because science represents only one approach to knowledge of the world, only one facet in a multi-faceted situation.

There are environmental education adherents, however, who hold the view that 'all subject matter is environmental'; [209] and that would mean integrated science is only a subset of environmental education. One is inclined to take Schmieder's position that environmental education 'is an action process, it relates to, and *builds upon*, the work of almost all other subject areas ...' [283] (emphasis added).

* This diagram was suggested by Professor Abraham Blum at the Nijmegen Conference.

Future developments in integrated science education in relation to environmental education

If integrated science programmes included social and aesthetic aspects of living, they would share a very important characteristic with environmental education - difficulty in compartmentalizing content in the usual manner of disciplines. This is practically impossible in the case of environmental education because environment, which is its integrating factor, would include everything. But, as was stressed in Tbilisi, science (ecology, to be specific) must form the bedrock of environmental education; and integrated science can often play that role better than separate sciences when the major focus is integration.

Integrated science can show in what ways applications of science affect natural and man-made environments, individuals, communities, and nations; it can teach young people how to gather evidence to solve environmental problems and to understand the bases upon which decisions and informed opinions regarding the environment are made. Perhaps most important, integrated science opens the door to a reasoned examination of the 'interactions between science, technology, environment, communities, economics, politics and value (belief) systems' [155]. As has been pointed out already, the concepts, skills, and attitudes which integrated science seeks to develop should serve the objectives of environmental education also.

The growing relationship creates problems. Both integrated science and environmental education in their present forms are relatively new fields of study and by their very nature and practice place strains on predominant current educational systems. Since integrated science potentially will have such a vast subject matter, questions of how much and which content to cover will loom large. The implications are serious because if teachers have to cover a given amount of content, they are likely to teach about it rather than let students learn in it. And that would destroy the soul of integrated science. In an attempt to alleviate the burden of content selection, integrated science education could be used to focus on the learner as in Figure 2. It would be kept in mind

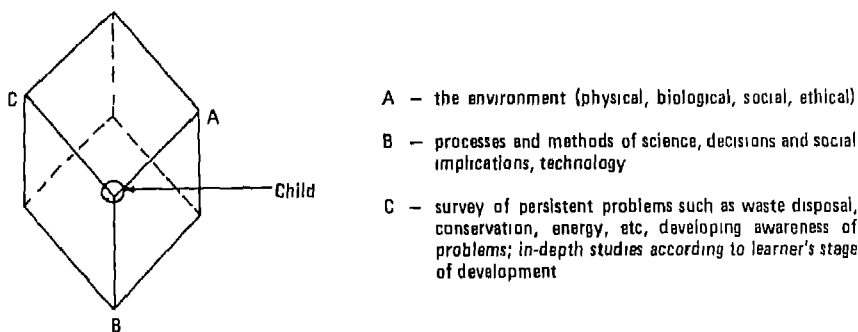


Figure 2. A framework for the selection of content for integrated science

that there are specific guidelines for selecting points of interest in the environment. It is also important to note that A, B and C are dimensions which are in continuous interaction. An example of this scheme in operation was furnished by Geller in her contributed paper. In centralized education systems, there would be co-ordination at local and national levels.

Even if content were selected in relation to the learner and his/her immediate environment, there would still be the question of identifying suitable problems on which to base learning activities. Thus problems have to be identified and 'problem searching' would have to be cultivated on the part of both the teacher and the learners. Then skills of problem-solving have to be developed. Inherent in problem solving in integrated science education are analysis of the situation, collection of data, value clarification, decision making and action. Unfortunately, value clarification is an area in which concrete illustrations at the classroom level are lacking. Decision making could be encouraged by means of games and simulation whereas action could include clean-up

campaigns and preventive activity.

Some education systems are characterized by national and even international examinations. A central examinations system would create difficulties and challenge the ingenuity of examiners to develop techniques which would encourage the approaches most favourable to the furtherance of integrated environmental science education. But examinations can play a key role in bringing about (or preventing) educational change.

Problems in teacher education will also arise. The teacher will no longer be a supplier of information and answers; he/she cannot have answers to all the problems the study of integrated science will lead to. Imaginative schemes aimed at equipping teachers with new attributes that integration will demand would need to be developed both at the pre-service and in-service phases. The special characteristics identified above as being an important contribution of integrated science education to environmental education would have to be translated into action programmes in a manner that would encourage their development in teachers and prospective teachers. A few new programmes exist, but ways have to be devised to equip teacher trainers with the skills they need to give requisite training to their own students.

At present, there is a paucity of knowledge and understanding of local technology appropriate and relevant to local and national conditions. Yet that knowledge is necessary if the contributions of integrated science are not to remain merely a promise. Curriculum developers, therefore, would need to explore this area and build 'idea banks' to assist teachers. Even more important will be the building of case studies to serve as illustrations.

The existing support systems in pre-university education may need overhauling to make it possible for teachers to have access to varied techniques and materials within the schools' budgets. Such rich provisioning is essential because 'the particular key which opens a new door for a particular child is not predictable', at least not easily predictable.

These practical problems are listed here not to discourage but on the contrary to demonstrate that a significant part of integrated science education represents, with a part of environmental education, a junction of knowledge, skills, and attitudes which our schools tend to ignore or to present in parallel lines with separate sidings. Somehow, a way must be found to extend the educational benefits of unity in diversity and of interaction and change (which integrated science can demonstrate so well) to environmental education world-wide.

SOME SOURCE MATERIALS

Connect. A newsletter published by Unesco, 7 place de Fontenoy, 75700 Paris, France. Edited by Joseph Barry and available free. Volume I, No. 1 (January 1976) described deliberations of the International Workshop on Environmental Education at Belgrade, October 1975, which established a charter which 'has laid down the principles and established the guidelines for the world-wide environmental education of a generation which spans the earth'. Vol. III, No. 1 (January 1978) contains a description of the Intergovernmental Conference on Environmental Education held at Tbilisi (U.S.S.R.) 14 - 26 October, 1977. It is a useful summary of the rôle, objectives and characteristics of environmental education and suggests some useful recommendations for policies and strategies.

Linke, Russel (ed.). *Education and the Human Environment*, published by the Canberra Curriculum Development Centre. This is a series of position papers in environmental education and includes a description of present practice in Australia.

Unesco. *Man and Biosphere Report* series. Paris, Unesco. Provide scientific information on selected topics in environmental science. No. 7 is especially relevant as it is devoted to educational activities. Nos. 3, 4, 5, 6 and 8 deal with the impact of human activities on selected environments; and No. 9 is relevant in the study of perception of environmental quality.

Future developments in integrated science education in relation to environmental education

Unesco. *Trends in Environmental Education*. Paris, Unesco, 1977. This book published in five Unesco languages is the most comprehensive document on current environmental education at all educational levels, in-school and out-of-school, specialists, youth and adults. The Unesco/ENVED documents prepared for the Tbilisi Conference are most important, especially ENVED 4 and ENVED 5 which deal with current problems of the environment and the Unesco/UNEP International Environmental Education Project.

See also [16, 155, 210, 269, 270, 271].



Our school

16. Future developments in integrated science education in relation to technological studies

Avi Hofstein

The products of technology, together with their accompanying sociological and environmental implications, are essential features of daily life. Nuclear powered satellites, energy production and conservation, high speed computers, automated systems, new materials and medicines and new methods of transportation are but a few examples, and it is interesting to note that, in each case, these new technologies have been preceded by a significant scientific discovery. Each of these examples demonstrates a symbiotic relationship between science and technology. It is difficult to give a precise definition of what comes under the heading of science and what under the heading of technology, but some distinction between the two will be helpful, in view of their close inter-relationship.

The famous physicist Robert Openheimer wrote:

'Science and Technology are symbiotic ... they are symbiotic because technology would be impoverished, blinded and crippled were it not for the new knowledge which is sought and found *for other reasons*. Technology gives back again to science a rich reward in new instruments, new techniques and new powers. It is this incessant feedback and reciprocal fertilization which make a sharp distinction between pure science and technology academic and dreary.' [416]

Science, it is suggested, is both the process and product of investigating nature, while technology consists of the application of scientific knowledge and research. It has been said [16, p. 16 - 7] that technology consists of techniques, procedures, processes and materials which are used to manipulate nature for the benefit of mankind.

Before the industrial revolution, which began in Western Europe, science and technology were virtually distinct domains. In the course of the past sixty years, empirical technology has been increasingly based on a framework of systematic reasoning. Lloyd Berkner [366] describes this development as follows:

'the crossover from empirical to science-based technologies occurred about the mid [twentieth] century ... by the year 2000 technology will have become almost completely science-based, deriving its strength from the constructs and basic generalizations of science.'

The science and technology interaction we have been talking about so far has a momentum of its own; the driving forces are well known, whether they be those of the academic researcher or the profit motive of an industrial concern. But our interest is in education. It would seem more than reasonable to find some parallel development at the various levels of the educational system. The need to introduce technology into science curricula is based on the assumption that in the

world no product of the human intellect exerts so profound an influence on the human condition or so capable of altering it as science and technology [233]. This is true both in developed and in developing countries.

Integration of disciplines at the *primary school* is no longer an issue. Therefore, the following discussion will be focused on the various types of schools at the secondary level, where integration will have the greatest impact. Before turning to the secondary school in detail, the tertiary level will be mentioned briefly.

Integrated science and technology at *university* level is already becoming a reality. Nowadays, there is a tendency in faculties of science [14] to encourage research in applied sciences. This is due to a rapidly growing feeling that universities train scientists who are too 'pure', and that there is an urgent need to strengthen the interaction between academic science and industry. Some integrated courses already exist in universities such as polymer technology, industrial chemistry, biomedical engineering and solid state technology [14]. These are all areas which have been developed on the basis of new discoveries made in the pure sciences by chemists, physicists and biologists.

THE SECONDARY SCENE

I want now to return to and concentrate on the secondary level (age 13 - 18). Almost all the secondary science curricula developed throughout the western world during the golden-age of curriculum reform (1960-70) were based on the conceptual structure of the discipline [396, p. 22] and usually did not attempt to include technological applications of the scientific concepts studied. To those who developed the 'new' science curricula, technology seemed at best irrelevant and, at worst, an interruption in the orderly development of the structure of the science being studied.

These science curricula which replaced even older materials are still very much in evidence. The inertia of the educational system is such that the replacement of curriculum materials can take up to a generation. This may be the cause of the visible decline in enrolment in the sciences, both in high schools and in universities [395]. This decline may well be due to the fact that the classical discipline-based approach is conceptually difficult and, at the same time, seems to have little relevance to the 'outside world' in general and to future employment in particular.

Since modern technology is an inescapable component of modern society, the integration of technological topics within an interdisciplinary science curriculum *may*, if it coincides with students' interests, help in fact to increase students' motivation [40, 270]. At the same time, the students' creativity may be fostered through projects that link school activities with the external world.

In developing countries, it should be easier to relate science to technology by drawing attention to the way in which science is used for the benefit of mankind.

Since 1970 the increasing attention given to the study of technology is reflected in the International Clearinghouse reports [201]. According to the 1977 report, forty-five science and technology courses have been developed, of which thirty projects were still active but *only* in seven countries. It seems that the trend to integrate science and technology started in 1970-72, and remains, in industrialized countries such as the Federal Republic of Germany, the United Kingdom and the United States.

The stated aims of most of these integrated projects are: to open a window into the world outside the school laboratory [377] and to link the sciences with technology so that the student will get a comprehensive, complete and balanced view of the nature of science as a human enterprise [269]; to demonstrate the aims of scientific technology, its achievements and failures, and the social, political and economic consequences of industrialization [196]; to motivate students and to

encourage them to study science by teaching them scientific concepts and ideas which have relevance [243]; to train personnel who will live and work in an increasingly technological society; and to promote a stronger correspondence between learning theories and subject matter, which will cater for both the more able and the less able students.

HOW AND FOR WHOM TO INTEGRATE THE TEACHING OF SCIENCE AND TECHNOLOGY

In order to discuss types of programmes, it is appropriate to consider first the various types of students at whom the programmes are aimed. A rough classification, but sufficient for our purposes, is to distinguish between two types of students at the secondary level; namely, those in academic schools and those in technical and vocational schools.

The characteristics of the technical school are that it is job-oriented and that future employment is based on applied science. The scientific demands made on students in technical schools are, in general, not heavy and hence science plays a secondary role to the main technological studies. On the other hand, in academic schools there is no particular emphasis on industrial career training. The classical examples of the academic school are comprehensive and grammar schools in the United Kingdom, Gymnasien in the Federal Republic of Germany, secondary school in Ghana and junior high and high school in Israel. In the academic schools, the rôles of science and technology are reversed, with science playing the dominant rôle.

Within these two broad categories it is useful to further subdivide (see Figure 1).

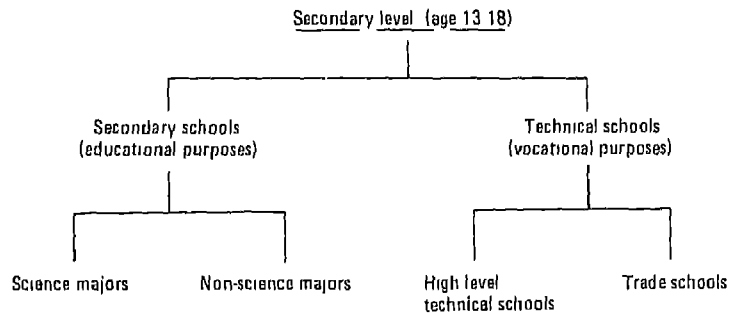


Figure 1. The secondary level.

We shall now list some of the curricular materials for these various types of student.

The integration of science and technology in secondary schools

A. Science majors

As the industrialized countries have become more and more technically sophisticated, the need for an ever-increasing number of people who are able to work directly or indirectly (e.g. in administration) at technically oriented tasks has grown. It is recognized by educationists [424, p.ix] that if students are going to be encouraged, or at least given a chance, to opt for courses in the applied sciences and technology, then the educational system must provide opportunities for them to get some feel for these subjects.

Technologically-oriented courses were developed for example by the Joint Matriculation Board [380] and by the Nuffield chemistry [424, p.ix] and physics [415, p.1] projects in the United Kingdom and as part of the curriculum of Chemistry for High School in Israel [365].

In Israel, several 'case studies' of the local chemical industry [411] have been developed for classes of students in the final year of high school who intend to major in chemistry. Chemical concepts are combined with a discussion of the problems arising from technology, economics and the preservation of the environment and cover such industries as copper mining and production, the production of bromine and its compounds, polyvinyl chloride and the plastics industry.

In spite of these programmes, university entrance requirements in many parts of the world still have a determining influence on science curricula. We must therefore ensure that universities will accept and support the introduction of technology into the school science curriculum.

D. Non-Science majors

Among the non-science majors are many students in secondary schools who are studying science without wishing to make a career of it. For these students, an integrated course should show a clear, relevant and balanced picture of the technological and scientific enterprise as a whole. Such a course was prepared in the United States at Stony Brook by the Engineering Concept Curriculum Project [422], *The Man Made World*. Liao and Piel [196] claim that:

'The course was developed to improve the technological literacy of the student, to give him that understanding of modern technology (its capabilities, characteristics, and limitations) that is so important if he is to cope with the world in an age of technology.'

The Man Made World integrates science, technology and social studies, including such topics as the interaction between man and machine, decision making, urban problems, traffic control and population growth. These are all complex problems which students can attempt to solve through system analysis, using information given in the text. An evaluation by the authors showed that this project, adopted by 1200 teachers, can indeed be taught to non-science students aged 15 - 18, because it is relevant. The evaluation also showed that the course increased student enrolment.

A course for the average student in a comprehensive school was designed by Richmond* in the United Kingdom. This course is an integrated physics-technology course based on the solar energy problem. Another example of a curriculum unit aimed at a similar population was developed in Israel in 1976 [394]. This curriculum in industrial chemistry is built around the study of the basic principles and processes used in the production of ammonia and nitrogen fertilizers and is in use in many Israeli schools. It aims to show how science and technology have been used to harness nature (e.g. the catalytic fixation of atmospheric nitrogen). Among other things, the unit demonstrates the changes that can be effected by fertilizers (the growing of better crops and increased food production, for example). Figure 2 is a schematic representation of this integrated industrial unit. In this unit the students study chemical concepts, not only as a body of knowledge, but also in connection with the technological processes which are based on them. This is an example in which the technological topic serves as a vehicle to introduce and motivate the study of scientific concepts. Such a unit could also be the basis for a course which integrates chemical technology and agriculture.

Another course which deals with the use of modern developments and scientific endeavour in agricultural technology was developed in Israel [368], and aims at students from both urban and rural areas. Students from developing rural areas tend to identify a lack of technical progress with the rural way of life, and a course in scientifically based modern agriculture may help to correct students' misconceptions.

* Personal communication at the Nijmegen Conference.

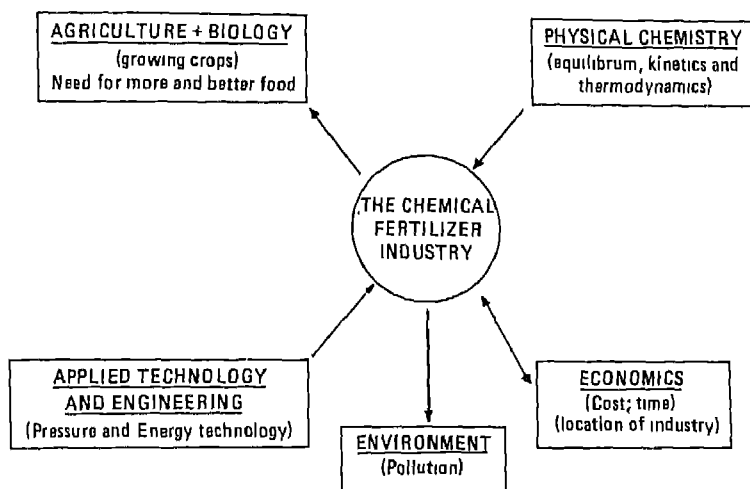


Figure 2 Schematic representation of an integrated industrial chemistry unit

It would seem therefore that the development of technologically-oriented science courses in developing regions must be based on close observation of people's activities and needs.

There are two ways to develop integrated science/technology curricula. The first involves replacing certain concepts in the existing science curricula by aspects of technology, either by the preparation of optional units or by the preparation of source-books for teachers. The second (more innovative) possibility is to provide new integrated projects. At the Nijmegen Conference, the first possibility was highly recommended.

The Integration of Science and Technology in the Technical Schools

One can divide technical schools into two types which differ in the level of sophistication and in educational aims, namely trade schools and high-level technical schools.

Trade schools are aimed at students who wish to be trained in specific skills or trades, such as carpentry, welding and printing. It was found [386] that these students have a low motivation to study basic sciences and mathematics. The students in such schools tend to be interested overwhelmingly in things rather than in ideas. It is suggested, therefore, that in such 'low level' courses, the best learning strategy is to integrate chemistry and physics (or mathematics) with technological studies in every suitable place. In other words, to include, in an integrated manner, only those scientific topics that have immediate relevance and that are needed for the understanding of the technological concept or skill.

One approach to developing a curriculum in this area would be first to analyse carefully the students' background needs and expectations. The results of this analysis would help in determining the course content, level and scope of integration. Obviously, the integration of science with the technical subjects will differ from country to country, according to the needs and demands for trained manpower by industry, agriculture and so on.

It is more than likely that in spite of the fact that the principles of curriculum development will be transferable from country to country, the actual course materials will not be transferred

so easily. International curriculum transfer is always a delicate and dangerous activity, but it is likely to be even more so in specific vocational courses, which need to be tailor-made to students' motivation, knowledge and environment.

High-level technical schools have been developed because of the needs of modern and sophisticated technologies such as electronics, automation, computers and hydraulics. Since the scientific background knowledge required for such courses is fairly broad, there are many opportunities here for the integration of science and technology.

An American report gives a statement concerning the role of physics in technology for technicians [357].

'The technician must have sufficient knowledge of the basic principles and phenomena of the science underlying his specialty to be an effective, comprehending, and perceptive worker with his or her professional counterpart and to be able to master the inevitable (and often rapid) changes brought about by technological developments'.

PROBLEMS CONCERNING THE INTEGRATION OF SCIENCE AND TECHNOLOGY

Some of the arguments in favour of the integration of science with technological studies have been discussed. However, there is still a serious drawback in that the teachers currently available have not been trained properly to cope with such an educational assignment. Teachers often claim [395] that because of the lack of information and resources, they cannot teach science-technology courses in an educationally sound and intellectually honest manner [270].

There are at least three ways to overcome this problem. First, more consideration must be given both in universities and in teacher-training colleges to the training of teachers in the following areas: applied sciences and technology, development and investigation of case studies, the interrelationships between science, technology and society, techniques of interdisciplinary research and decision making. Second, teachers' lack of resources can be remedied by centres which will be essentially sources of technological information collected and obtained from local industry (e.g. the Schools Information Centre on the Chemical Industry in the United Kingdom). Such centres will be responsible for establishing the link with industries. Finally, teachers could be provided with a source book to help those interested in this new field.

CONCLUSION

In summary, we are living in a technological era in which changes are rapid. The responsibility of the educational system is to keep up with these changes and to adapt and develop appropriate curricula with concurrent effective dissemination, follow-up and evaluation. This implies that we must move from short-term curriculum development projects, which have been (and are still) so common, to long-term and dynamic curriculum development projects in which new curricula can be developed and revised over many years. Such curricula should certainly include those integrating science and technology.

17. Developments in integrated science education in relation to nutrition and health education

Isaias Raw

SUMMARY OF WORKING GROUP PAPER

WHY HEALTH AND NUTRITION?

With the expansion of secondary school education, the innovative science curricula of the 60s, while contributing to the preparation of a scientific élite, have become a meaningless intellectual venture for the majority of students. Most of them cannot deal with abstract concepts, much less apply the knowledge at a later stage in their lives. For the average student, science should deal with their present realities.

The re-introduction of technological applications would motivate some students and play a role in the preparation of professionals, but the majority will remain unmotivated; more people are interested in astrology than in how television works. Ecology and the problems of the future of mankind, discussed in the chapters by Dyasi, Terlouw and Lewis, integrate science teaching and stimulate many students, but will still not reach the large majority unmotivated to science.

There is no topic that is more real, relevant and personal than the student's own health and nutrition, and these are also a major concern of society. Certain preventable but incurable health problems originate in the first two decades of life, including calorie-protein deficiency and excess caloric intake, conditions affecting a large majority of the poor and the affluent populations.

Within a single individual, even in the most sophisticated societies, there coexist two cultures, one acquired through formal education, the other including the traditional culture transmitted from generation to generation but also including a para-scientific culture that is being continuously generated and transmitted more efficiently than the formal education, and having a more profound effect. The street culture of miracle drugs and herbs, natural foods and diets, is much more influential than our present approach in formal education of presenting accepted truths. If education were to integrate science with health and nutrition education, providing an objective presentation of the rationale for health and nutrition recommendations, there is a much greater chance of acceptability to students.

INTEGRATION OF HIGH SCHOOL SCIENCE WITH FOOD, NUTRITION AND HEALTH

In the last decade there has been international and public concern about famine, malnutrition and

its possible permanent impact on intellectual development. The Sahel famine has been much more real and less remote than the problems of ecology. It is amazing, therefore, how slowly education is responding; among more than 500 science education projects mentioned in the latest International Clearinghouse Report, only a few seem to include nutrition!

As man modifies the Earth's biosphere, it is difficult for a modern biology course to omit some aspects of human food and nutrition. Indeed there are some well-treated sections in the Nuffield and Biological Sciences Curriculum Study (BSCS) biology projects, and Nuffield Advanced Chemistry has a special volume on food technology and chemistry. Israel's Let's Grow Plants, Agriculture as Rural Science is an agriculture-biology module. Still, none of these uses food and nutrition as an integrating topic. The only on-going project that does so is What People Eat, an integrated chemistry-nutrition course being developed at MIT for secondary school or college.

Here Professor Raw went into some detail about the strategies used in What People Eat, showing how real problems and real data serve to achieve a wide variety of important aims of science education. Referring to the three types of curriculum design described by Griffin and Light in relation to nutrition education, he pointed out that all three are used in What People Eat: rational-empirical, where authors construct a logical sequence of information and learning experiences, engagement, centred on students' involvement in activities related to a problem of interest to them; and emergent, responding to the changing interest expressed by the learner.

As with nutrition, most modern biology curricula contain some references to medicine and health. There are also some special health courses and a few outstanding textbooks. The Lawrence Hall of Science is initiating a Health Activities Project, preparing not a curriculum but a number of modules for grades 5-8 to supplement health science and physical education programmes. The Educational Research Center at MIT has plans for an integrated science project built around the processing of information received by man from his environment, integrating physics with physiology and psychology, and discussing sense organs, the nature of stimuli, brain physiology, cybernetics and the nature of intelligence.

To bring about the innovations that are needed, I would not recommend the replacement of existing official curricula with new and uniform ones. This could depend on official approval in centralized systems, and anyway it is better to make available a variety of styles and content, providing for the interests and characteristics of the learners and the variety of needs of society. Curricula already in use lend themselves to limited introduction of novel approaches. Krasilchik, for example, reports how students in an environmental integrated science project in Brazil are asked to bring recipes from their homes for analysis in terms of a number of matters with implications for science and its processes, nutrition, technology and society.

SPECIAL ISSUES IN ELEMENTARY SCIENCE EDUCATION

In the developing countries a few years of education is all society can offer to a large proportion of the population, and this is expected to produce a lasting impact on their lives. Ahmed in his paper spoke of the need for sensitivity to the real problems of the community. Attention to only the principles and processes of science will not result in transfer to the solutions of an individual's own problems. Parents, having the same limited education, will not complement formal education so schools must bring education to the parents through their own children. You cannot expect children to wash their hands before meals if their families do not do so. If people are to believe in microbes, parasites and the value of fertilizers instead of the street culture I mentioned earlier, we must use children to convince their families after educating them in the scientific approach.

We must therefore actively involve the child in all the processes of science just as we do with a child who is learning to walk or ride a bicycle. Giving him a book on the subject is unthinkable.

The paper described in some detail how such principles are put into practice in the unit Micro-gardening of ESS; in the Funbec (Brazil) and Israeli Science Teaching Centre projects developed

by the author, and in the Brazil series 'Life and Food' and 'Life and Health'.

CONCLUSIONS

I have tried to provide examples that may be relevant in developing countries. But each school system must search for the problems and solutions appropriate to its own society. The most the international science community can do is join its resources in producing materials, prototypes and novel experiments adaptable to local situations.

The full text of the paper (23 pages with bibliography) is available from the author.

WORKING GROUP REPORT

INTRODUCTION

In his paper, Raw has made the point that the individual needs to be shown the relevance of science to himself. He has also argued that we must examine ways of integrating science in itself and with other issues, and strategies for these integrations can be found in the fields of nutrition and health education. The working group, in arriving at suggested strategies, began with an exploration of the needs.

LONG-TERM PURPOSES OF HEALTH AND NUTRITION EDUCATION, AND THE ROLE OF INTEGRATED SCIENCE

This discussion began with a consideration of what is meant by science education in the first place, a question to which of course no simple answer could be found, but a close relationship among science, health and nutrition is clear. This relationship in the context of education is shown in Figure 1. The contribution of health and nutrition education to the well-being which is

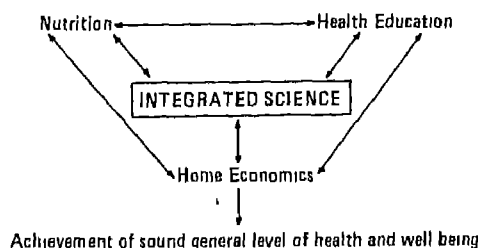


Figure 1: Nutrition and health education in the context of integrated science

the ultimate aim was seen to be as follows: relevance to the pupil; social consequences (prevention of the long range effects of malnutrition, whether from shortage or excess of food, and prevention of infection and parasites); acquisition of the knowledge necessary to ensure prevention, acquisition, through this knowledge, of scientific skills and processes; provision

of care for individuals in the family setting, leading to a transfer of science to the solution of the practical problems of everyday living (application could lie partly within the field of home economics); better physical and intellectual development arising from sound nutrition and health practices; identification with understanding of the propaganda of the mass advertiser; and a scientific approach to nutrition and health education which can be offered to makers of social policy.

EXPLORING THE NEEDS

In advanced countries, young people are subjected to, and accept, commercial advertisements of questionable accuracy because of the divorce between the knowledge given to them by schools and actual eating patterns and health practices. Meanwhile, in some of the less developed countries, the people adopt other inappropriate feeding practices. Infectious and endemic diseases arise when lack of food causes low in-built resistance.

As indicated in Raw's paper, more must be done to transfer science to real life. This would seem to indicate a problem-solving approach to teaching and learning. Attention must be given to process and decision-making skills and their application at increasingly complex levels. There is a need for a systematic scheme of instruction for various levels of education.

POSSIBLE STRATEGIES

Presenting science in the context of real life could include personal hygiene, a balanced diet, production, preservation and preparation of food, first aid and safety in the home, and child and maternity care. Curriculum decisions must be based on the age, sex and interests of the child. In this context, two United Kingdom projects are relevant, the Schools Council project Home Economics in the Middle Years (8 - 13 years) and the Nuffield project Science in Home Economics (13 - 16 years).

'Where should the science be taught? It can take place in the science laboratory, in health education classes and in home economics classes according to the activity.

We must consider how integrated science is to be used in health and nutrition education and how we can ensure that there is transfer of knowledge from this education to everyday situations in the whole life of the pupil. It seems that we are concerned with survival knowledge and skills.

For success in the teaching of integrated science, relevance, motivation and activity are crucial. Essential approaches are learning by re-discovery and 'doing', and goals from real life, such as those related to the food that the child eats and concern for one's health. Raw has pointed to the establishment of a non-scientific culture based on mis-information, and the teacher is faced with the task of devising a curriculum that attempts to remedy this.

Although science inevitably involves practical work, it is recognized that there are problems in respect of time and availability of equipment, particularly in developing countries. Local production of inexpensive equipment is often a solution. There is also the difficulty of transferring knowledge gained from animal studies to human beings. One alternative to practical work is the use of data to be examined by pupils, who will then use the evidence to draw conclusions in a scientific way. Another alternative is the use of case studies, but here there are problems first of identifying sources of information and then of determining their reliability.

LEVELS OF IMPLEMENTATION

Primary School

The principle of 'readiness' must be borne in mind, primary school children are ready for simple and concrete forms of science, and Bruner's view is that ideas which are important can be expressed simply and powerfully. This is a most important age group in view of Raw's contention that in many countries this is all the schooling most people get, and we should try to use the child as an educator for his family. There is bound to be conflict between the views of the teacher and the community's customs, traditions and superstitions. However, the utilization of those customs and traditions containing an element of folk wisdom may help to bring about reconciliation.

Secondary School

The group advocated a spiral curriculum which moves from the concrete to the abstract, increasing the level of complexity in parallel with the child's development. Whether integrated science displaces or enriches other areas of the curriculum depends on the content of the related areas and the local situation.

Out-of-School Education

Adults can be reached through educational television, mobile film units in rural areas, consumer advice bureaux in urban areas, and professional field workers (doctors, nurses, welfare workers, community dietitians, nutritionists and home economists working in the community). Some members of the group saw the home economist as being vital in this field of informal continuing education. She stands at the interface between advances in science and technology on the one hand and the individual user of products and services on the other. She can interpret to the user the possible applications of these advances, helping him to cope more effectively with the practical problems of everyday living.

Even if we can teach children, there remains the need for a constant combat against mis-information acquired from others and through the communications media. But the task will be easier if children in school are given a healthy scepticism as a foundation for lifelong decision making ability.

Makers of Social and Educational Policy

Policy makers might be influenced by an awareness of the heavy financial burden placed on the community by inadequate nutrition and low levels of health care. (This is not to say that the individual should not take increasing responsibility for his own health and well-being, and the happiness of human beings cannot be expressed solely in financial terms, as Terlouw clearly said in his paper.) Attitudes and values in respect of regard for persons are involved. Policy makers can be strongly influenced by the scientific community and by an informed body of public opinion.

RESOURCES

In addition to the materials described in Raw's full paper and itemized in his bibliography, a number of other resources for educators were identified: publications of WHO, FAO and Unesco (in his chapter, Ferreyra also refers to these); national information offices; Schools Council (United Kingdom) projects (Health Education 5 - 13, published, and 13 - 18, in progress, Science 5/13); Nuffield projects (Working with Science for 'new' 6th forms and CECIS, for up to age 16); ISIS published by Ginn; and work done by FUSE.

CONCLUSIONS

Our concern is to make science more relevant in response to human need, and the emphasis must be on its social context. In a world of finite resources which are rapidly being depleted, greater efficiency of usage is required.

18. Special problems of curriculum diffusion nationally

B. G. Pitre

SUMMARY OF WORKING GROUP PAPER: DIFFUSION

Today the emphasis is on change. More than at any time in the past, political, scientific, social and educational systems are changing; and, where PSSC began a revolutionary movement twenty years ago, science curriculum development is now part of our lives. Evaluation reports are generally favourable but, as Krasilchik said so frankly, reality may be very different [270, p. 121]. The simple model of 'develop, evaluate and implement' does not seem to be working, and there is growing concern about the complexity of the process of implementation and the slow pace of adoption. Problems of curriculum diffusion have been identified at a number of international meetings, including the Maryland Conference (1973), the Symposium on the Evaluation of Integrated Science Education (Oxford, 1975) and the Edinburgh Conference on Physics Education (1975).

Yet the problems have not been treated seriously enough. Science educators argue that the problems are soluble by improving training, programming instruction, grouping children, allowing time, using educational television and other strategies. Others argue that, since man is rational, the system will adjust and good (or truth) will assert itself. Still others defend themselves by saying that their business is innovation, not diffusion or social change. We might, however, do well to remember the words of Mao Tse-Tung who led a fifth of mankind through a revolutionary social change.

'Everyone knows that, in doing a thing, if one does not understand its circumstances, its characteristics and its relations to other things, then one cannot know its laws, cannot know how to do it, and cannot do it well' [388, p. 75].

It seems to me that, as science educators, we have to recognize our social responsibility and accept science education as, not an end in itself, but a means to an end. Therefore, since integrated science has a social science element, do we not have a heavy responsibility for its diffusion, even if we risk straying too much into issues of general education?

One of the foundations of educational research and evaluation has been the assumption that they lead to course correction, but this assumption is questionable. Atkin, over ten years ago, pointed out that models based strongly on engineering approaches fail to recognize the competition among diverse value systems and power groups [363, p. 388]. Two years later, Kerr drew attention to inadequate attention to evaluation [404]. Welch quite recently has stated that research on the effectiveness of formative evaluations as a means of improving decision making is virtually non-existent [334, p. 29]. And Yoloye, referring to the African Primary Science Programme (well

received by science educators) has said

'Initially, it was believed that the purpose of evaluation was to convince African governments of the worth or otherwise of the programme so that the programme could be adopted or rejected. Within two years of the programme's operation, however, it quickly became clear that the essential factors in the operation had little to do with evaluation' [348, p. 132].

It looks as if we must identify the factors, apart from evaluation reports, which influence decision making by educational administrators; and determine the effect of these decisions on curriculum diffusion.

We should now give some thought to the people who make the decisions. In the United Kingdom, where the teacher usually makes his own choice of curriculum, implementation will probably follow the five stages shown in Figure 1.

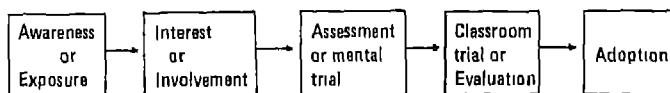


Figure 1: Stages in the implementation process

In many other countries, however, the implementation decision is taken, not by the teacher, but at the national or state level. Sim Wong Kooi has drawn attention to a system in which the teacher is expected to (and does) follow directives passively to avoid being taken to task for initiatives. In such a system, schools are expected to adopt the programme eventually and 'trial' is merely for the purpose of making minor adjustments [306, p. 174].

Yet implementation must go beyond administrative decision to use the new materials, the organization of in-service courses, and the setting up of new examinations. If the children do not learn, diffusion has not taken place. I should like to define curriculum diffusion as the process by which a particular educational programme spreads from the source of innovation to the classroom. The process involves communication of philosophy as well as techniques, and the teacher has to be convinced. Perhaps our past claims of success have arisen from lack of clarity about the terms 'diffusion' and 'implementation'. In India, there is a difference of opinion about whether the Unicef-sponsored middle schools science education project has been a success. An explanation for this difference may have been supplied by Werntz, at the time director of the Minnesota Mathematics and Science Teaching (MINNEMAST) project.

'The procedures for support of the curriculum development movement have been remarkably successful for producing sharp improvement of school materials but almost totally inadequate for carrying the results into general practice. The defect has been with the tacit assumption that school curriculum development is basically product oriented' [451].

Resistance to change develops at various levels in a society. The report of a conference in the Philippines has contrasted the common slogan in Asia for problem solving (which includes critical thinking, self-reliance, independence and liberation) with the reality that the problems selected for the classroom were invariably contrived, academic, and unrelated to real life [428, p. 22]. Biggins has drawn attention to the particular social problems of the underdeveloped countries and the less privileged sections of society when he writes of the conquest of nature as being linked to the conquest of man, and suggests that modern science is antagonistic to

fundamental human values [26, p. 9]. Perhaps there is a certain lack of faith in the social system that curriculum diffusion in science seeks to establish?

THE SOCIAL SYSTEM MODEL FOR CURRICULUM DIFFUSION

Decision makers need a model from which a strategy for a particular situation can be developed. Such a model is suggested in Figure 2.

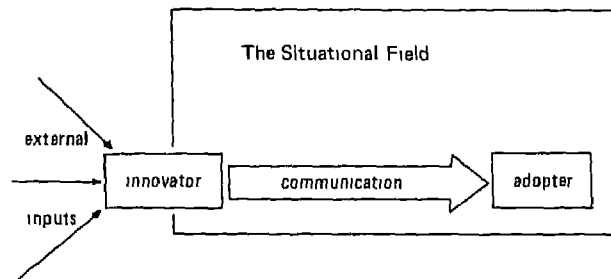


Figure 2' The social system model for diffusion.

In applying the model, one must take into account the historical and sociological factors which influence social values and characterize them. Since education is a social system, its response to any external stimulus will be an attempt to preserve and transmit the heritage and values. Using this premise, that an attempt to change faces an attempt to support continuity, we should analyse the separate elements in the model.

Nature of the Innovation

Where the innovation is radically new and fresh, there is quick interest, and the motivation of trial teachers is high. Since the Nuffield courses carried the heuristic approach to its extreme limit, they gained world-wide respect and publicity. The disadvantage of a radical approach is that it is subject to closer scrutiny and arouses more scepticism. Mismatching with existing educational norms is more evident and arouses greater opposition.

Conversely, a new curriculum closely matching existing practice will be supportive of current norms and values. However, if the change is insignificant, it is no innovation. And in a large country like Nigeria or India a programme may match current practice in some regions but be very different from that of others, so that a uniform national course is bound to face obstacles in diffusion.

Teachers like to accept a curriculum in small steps and texts and equipment are taken up long before there is understanding about the grand generalizations and concepts (the knowledge component) and the inquiry skills, so that the materials tend to be used in traditional ways. Another reason for speedy implementation at the level of texts and kits is the social and political pressure on innovators and administrators for concrete evidence of change; better learning takes much longer to demonstrate than better facilities.

In short, a complex and well-integrated curriculum is difficult to comprehend, communicate, implement and evaluate. These processes are much easier with a modular course, content and

material based, and not too different from existing courses, but the educational gain is small.

Nature of the Innovator

The innovator¹ has special knowledge, contacts and exposure, and consequently status and influence. Rather than being dependent on continuation of the status quo, his professional standing is likely to increase if there is innovation. The prestige of himself and his institution is likely to attract funds. He is, however, remote from classroom realities and is not as accountable to the community as is the classroom teacher. Katz and Kahn have drawn attention to the weakness of an approach which depends on individuals for organizational change without regard to relationships and the social system [403, p. 52]. The innovator as described has much to contribute to educational reform; but in his dealings with the adopters (the teachers), he should not bring his status and influence into play; instead he should be able to communicate with the teachers and show that he understands the system and the teachers' problems. Two-way interaction, including honest feedback to the innovators, is essential.

Nature of the Adopter

It is now generally accepted that the teacher must go through the stages of awareness, arousal of interest, assessment, evaluation and finally adoption in the same sequence. Confidence can be built by the right kind of teacher education, and awareness and interest can be induced by involving the teacher in the planning of the curriculum. Science teachers' associations help to identify the teachers who will be most useful. It is worth remembering that teachers form a social system which has certain standard patterns of response to outside suggestions. The resulting cohesiveness, together with the opportunities for interaction provided by the social system, can be utilized in accelerating diffusion.

Nature of the Communication

The impact of the message depends as much on the method of communication as on the idea itself. Adoption is the outcome of learning and we would do well to apply learning principles in arriving at strategies for effective communication. Indirect influence, suggestion and persuasion are likely to be more effective than propaganda and direct instruction. Teacher education courses should be integrated, inquiring and based on open-ended problems if it is our intention that school courses should have the same characteristics. A modern trend is to use mass communication, radio and correspondence courses and similar techniques, in the attempt to reduce time and distance in extending the benefits of science and education to more people; but studies indicate that the outcomes are in fact greater social distance and increased time lag before adoption [420, p. 112]. Other difficulties are faced in countries where transfer of information is rooted in authority and where curriculum implementation has to filter through a pyramid of board administrators, teacher trainers and so on before it reaches the teacher. In such a system, it is important to preserve the fidelity of the philosophy and to recognize that different communication techniques must be employed for the different target groups.

The Situational Field

Whether or not the situation is responsive to change depends on a number of factors, such as the educational level of the masses, the political system and the cultural norms. In traditional (as distinct from modern) societies, the interpersonal relationships within a family, between teacher and taught, and among members of the community are stable and strong. Non-material values,

1. Here I distinguish from the adopter: the innovator in this context is the breed of educators who play a leading part in the conception and later processes but are not classroom teachers.

such as friendliness and simplicity, are themselves valued more than economic gain and time-saving gadgets. The technology is less developed and the flow of information is through informal channels. An example of the unexpected comes from Fiji, where a new curriculum was developed with UNDP assistance, the teachers looking up to the consultants for help. But when one school dropped out during the trial stage, there was more harm done than the good done by all the others. Since education is national and has characteristics peculiar to a given country, it is not surprising that the principle of adaptation rather than adoption is now well accepted. One example among many comes from Chile, where the primary science programme of 1965, based on the AAAS S-APA, is very different from the original curriculum, having being adapted for a different social and economic setting.

CONCLUSION

Diffusion on a national scale must take account of the social and cultural norms of the society unique to the country as a whole or even to parts of it. Innovators must recognize the stress caused by science and technology, and should recognize that conservatism lends stability. They should understand that resistance to change arises from a survival instinct that asks for time to absorb ideas and techniques into a cultural pattern. The strategy seems to lie in identifying the small groups that encourage modernization and using them to build a network into a critical mass of individuals and groups that will achieve the diffusion for which we are aiming.

SUMMARY OF WORKING GROUP REPORT DISSEMINATION AND IMPLEMENTATION

Early Analysis of the Problems

Some of the problems associated with dissemination and implementation might be avoided if they were anticipated in the early planning stage of a new programme. A logical first step would be an analysis of problems known to exist in the particular national context, and examples of such problems may be found throughout this volume and elsewhere in the literature on integrated science education.

Composition of the Innovating Group

It was recommended that this should consist of a working team in association with agencies that would act as consultants. The nature of these agencies and their relationship with the working team are shown in Figure 3. This model should ensure a strong national orientation, but external

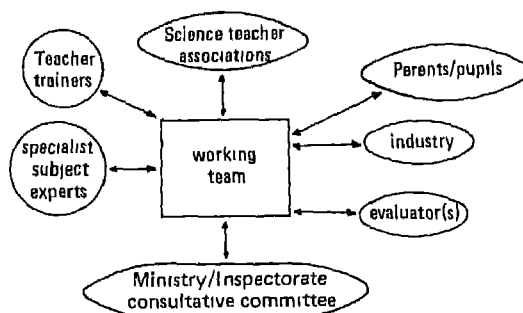


Figure 3 Composition of the Innovating Group

contribution to the innovation could be invited by the working team.

The working team should consist largely of practising science teachers. In addition, it would have some teacher-educators and one or more curriculum advisers, the latter being ideally full-time professionals with a knowledge of the education system of the country. Their rôle is seen as a co-ordinating one. In some countries it might be appropriate to include people with other kinds of experience as long as the group remains teacher-centred. Collectively, the team should have an awareness of the social and cultural characteristics of the country and its current mood, knowledge of science appropriate to the proposed programme; knowledge of the psychology of learning and other professional matters, and knowledge of the national educational system.

Within the innovating group as a whole, consultancy should be a two-way process, and practising teachers would be encouraged to assume a key rôle. Specialist subject experts would be drawn from the fields of social science and humanities as well as science. The evaluator(s) would be closely associated with the working team from the initiation of the project.

Responsibilities of the Working Team in Diffusion

One of the responsibilities of the working team is the exploration, in the national context, of lines of communication between the innovation group and the teachers who are expected to implement the programme. Figure 1 of Pitre's paper is expanded here as Figure 4, which shows that the

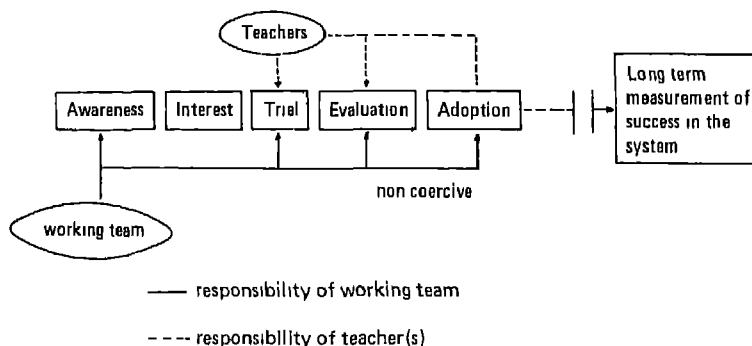


Figure 4 Stages in the implementation process and responsibilities of the working team and teachers

responsibilities of the working team are parallel to those of teachers, but are wider. The initial responsibility of the team is thus to produce an awareness of the programme in the teachers. Should there be interest, the team then initiates and assists with trials, evaluation and adoption. In addition to planning the dissemination, the working team's responsibilities include longer term action. It should ensure that non-trial teachers have opportunities to gain direct experience of the programme. There should be provision for continuous support for the teachers through, for example, science advisers and in-service programmes. There should be planning for the resources needed for implementation. And there should be planning for a long-term evaluation. Finally, there should be planning for the working team's own demise, the handing over of responsibility to disseminatory teams of teachers with experience of the programme.

19. Special problems of dissemination and implementation of integrated science regionally and internationally

Jan Vaernewijck, M. Saber Selim, David Lockard and
Karl Frey

The Working Group was able to consider working papers from Dr. Selim, Mr. Vaernewijck, Professor Frey and Dr. Lockard. This chapter contains summaries of the working papers from Mr. Vaernewijck and Dr. Lockard, papers revised by Dr. Selim and Professor Frey, after the discussions, and a short report from the Working Group.

REGIONAL DISSEMINATION OF INTEGRATED SCIENCE EDUCATION

Summary of working group paper by Jan Vaernewijck

When we are dealing with curriculum issues on a regional scale, we should recognize that a part is played by differences in culture, economy, politics, school systems and language. For instance, while the English-speaking West Indies has WISC, the French-speaking Caribbean, overseas departments of France, is excluded. Latin America, a very large region with two languages, has a variety of political systems. North America is fairly homogeneous, but until now French-speaking Quebec has not been involved in regional activity. English-speaking West Africa has, for example, the West African Association of Science Teachers (WAAST), while other countries in West and Central Africa, Madagascar and Reunion, follow a practice like that of France. In Asia there is a similarity among countries which have, at least historically, a background of English as a language of instruction; and there is a different commonality among the countries served by RECSAM. Of the countries in the South Pacific, only Australia has done much about dissemination. Europe, Western and Eastern, has differences in political systems, language and outlook. As for the Arab world, Saber Selim refers in this volume to the unifying influence of ALECSO.

Dissemination has a strong element of communication between educational authorities and teachers, and significant contributions have been made by such regional science teachers' associations as CROASE, WAAST and FUSE. Europe, although it has GIREP¹ for physics education, has no regional association committed to the dissemination of integrated science education. It is probably to the science teachers' associations that we should look for the greatest potential in regional dissemination; even a regional association for a single discipline can have a very influential rôle.

In dissemination, motivation is crucial. Authoritarian educational systems, in which curricula

1. Group International de Recherche sur l'Enseignement de la Physique

are imposed from above, are unlikely to motivate teachers towards integrated science. A more effective motivator could be the external examining body in those regions where that type of examination is a powerful determinant of curriculum. In the development of the integrated science examinations, there needs to be co-operation with the teachers. In their training, science teachers should be prepared for integrated science. There seems to be some relationship between the discipline of the teacher and his motivation towards integration. Biologists, perhaps because of their concern for the environment, respond first. Next come the chemists interested in chemical pollution. The last people to support integration are the physicists.

Mr. Vaernewijck suggested that radio and television could be very useful in regional diffusion of integrated science, and gave details of a new series of Flemish programmes, both for schools and for adults. He made a practical suggestion for accelerating progress in Western Europe working through Directorate General XII of the Council of the European Community, contacts could be established with the ministers of education of the European Economic Community (EEC).

DISSEMINATION AND IMPLEMENTATION OF INTEGRATED SCIENCE EDUCATION REGIONALLY

M. Saber Selim

Regional activities in science education have involved many countries and, in particular, Unesco's pilot projects in science teaching have been regional ones, for example projects in physics in Latin America, biology in Africa and mathematics in the Arab region. A specific example of regional co-operation is that of ALECSO, which has a project in integrated science education as well as projects in the teaching of biology, physics and mathematics. All of these are being developed and disseminated in twenty countries, and the processes are helped by the fact that the countries have the same language of instruction (Arabic) and common aims. Another example is the Caribbean Regional Science Project, a joint enterprise between the British Council and the University of the West Indies.

A regional enterprise presents opportunities and challenges different from those facing a national project. In particular, a region provides a much richer pool of expertise than can be found in a single country. This paper outlines some of the problems and strategies of the ALECSO integrated science project, which appear to have been similar to those of the RECSAM, SEPA, Latin American and other projects.

Problems and Strategies

An early problem is the difficulty of reaching a common concept of integrated science. As was clear at the conferences in Varna, Maryland and Nijmegen, integrated science means different things to different educators. Arriving at agreement demands time, hard work and patience. In the Arab region it took one year, including two one-week meetings, before there was an agreed definition of integrated science and the outline of a curriculum which met this definition. The definition adopted in the end was based on the unity of the universe and of science, which tries to give an explanation and understanding of natural phenomena through unity of purpose, content and process. To illustrate this definition, many concepts such as equilibrium, change, unity, diversity and energy were presented at meetings of experts from the region, Unesco, the British Council and projects in Europe and United States. This is a critical initial step. Unless the project is founded on a concept of integrated science that satisfies everyone, subsequent steps will be in conflicting directions.

In a regional integrated science project, two kinds of integration are involved, integration of science and integration of the countries in the region. A regional curriculum needs a core which achieves both kinds of integration, the nature of the core being specific to the region. It should meet the needs of each country within the region, being flexible enough for local adaptation. The

core should ensure that science is integrated, not merely combined. The group that develops the core must clearly consist of educationists, scientists, teachers and supervisors from all over the region. The core chosen for the Arab region was an environmental one, which proved handy and flexible, adaptable to local environments without sacrificing the essentials of science and educational principles.

Another early task is the identification of people who are competent to act as leaders and who also believe in integrated science. Many good educators and scientists are unsuitable on either one criterion or the other. Selection and training of promising teachers and supervisors is rather more difficult in a regional undertaking. It is useful to begin by choosing a team of trainers from those who planned the programme, constructed the curriculum and prepared the materials, people intimately familiar with the philosophy and dynamics of the programme. These are now regarded as a family that is trying to increase its membership with the aim of promoting the programme. Scouting for new local members of the family should begin in the earliest stages and should continue through the life of the programme.

Even if they are not to play a central part in the project, there are several groups whose commitment is essential for success. Some administrators, scientists, parents, supervisors and teachers commonly lack enthusiasm for change or actively resist it. This is a delicate problem which must be dealt with carefully and patiently. To convince people of the value of innovation, specifically towards integration, regional experts can work along with local leaders in seminars, lectures and meetings, exchanging experiences which have arisen locally and in other countries. Meanwhile, there is competition from parallel courses in general science, combined science or the separate disciplines. To some extent, solutions to this problem exist at the national level, because the government, science teachers' association and other local institutions can exert an influence. But what can regional headquarters do if solutions are found in some countries but not in others? Answers seem to lie in regional universities (e.g. Universities of the South Pacific and of the West Indies), regional science teachers' associations (e.g. CROASE, WAAST) and regional science centres.

There is no need in this paper to justify the statement that teacher preparation is crucial to success. Meanwhile, there is the world-wide problem of a shortage of teachers' college professors who can teach integrated science successfully. A regional project can form the available few, together with curriculum planners and outstanding teachers, into flying teams to serve the whole region in in-service and pre-service courses.

Even within a region, the principle of 'adaptation not adoption' applies. The curriculum produced centrally in the region must be modified locally. Cultural, socio-economic, environmental and other differences mean that books and other materials should have a local personality while their central themes have a regional coherence. The adaptation will take place after pilot trials involving local professionals (teachers and supervisors) who will later share their experience with the regional experts. In the Arab region, the result has been different textbooks and other materials for each country, but a common philosophy. A general strategy for the preparation of the trial materials is to have common general objectives for understanding, skills and attitudes, but to provide a good variety of examples.

Apart from the usual problems facing pilot trials, a regional project is faced with the organizational problems inevitable when several nations are involved. New designs are needed for the pilot phase, and it is suggested here that, since the particular design must depend so much on the characteristics of the region and the countries within it, each region must be innovative, even at the stage of planning for formative evaluation.

In the Arab region, most educational systems have a 6-3-3 structure (primary - lower secondary - upper secondary years). There are, however, exceptions and other regions may show an even greater variety. Such variety raises the problem of where to fit the innovations in integrated science education into the educational ladder. Some countries of the region may have a rigid examination system which is not compatible with what the project is trying to do.

Within a region, there is bound to be a spectrum of national wealth. This may be so wide that the country at one end of the spectrum can provide schools with all the materials they can use, while the country at the other end can hardly afford the humblest of textbooks. This range will affect a great many resources for science education, including laboratories and teacher education. It follows that every regional project should tailor its demands as far as possible to the resources of the poorest country. Where there is regional production of materials in the early phases, these materials should be inexpensive, in order to convey the idea that expensive materials are not necessarily the best. The regional body can make suggestions which help the individual countries to assess priorities, and can provide concrete help by allocating its own resources according to need.

The continuous evaluation and modification that are needed in order to avoid a static curriculum are best carried out as joint activities between the central team and local leaders.

Future Prospects in Regional Approaches to Integrated Science Teaching

The spread of integrated science teaching is inevitable, at least in general education. We have already passed the stage where a few scattered countries developed programmes, and the interest is now world-wide. There is reason to believe that future developments will be much more regional than in the past. It is not only in education that there has been a trend towards co-operation among bodies in countries or states that have a common background, and modern communications and transport are leading to the development of regional identities.

In spite of the problems discussed earlier in this chapter, there is much to be gained from a regional programme as compared with separate national programmes. There is better utilization of expertise, and, especially in educational and cultural matters, the countries of the region become more closely knit. Efforts and mistakes are not replicated. There is likely to be improved communication and dissemination of information, both from outside the region through to the classroom teacher, and from within the region to the rest of the world, especially if there is a regional science centre with local offshoots. Decision-makers at all levels are likely to have more confidence in a regional innovation, and are more likely to help in its implementation.

Finally, a regional curriculum project is likely to find greater interest and co-operation from regional and international bodies, which are more interested in regional work than in national activities.

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Discusses the status of science education in developing countries. It presents the importance of science for the different strata of the different societies. The article stresses the importance of regional and national efforts to develop science education.

Jacobson, W.J. Integrated science programs for schools and colleges. In: [269, p. 67 - 79]

Presents the different factors that should be taken into consideration while developing a

programme of integrated science education; many approaches to curriculum design are discussed, including the integration approach.

Razafy, E. Integration of science and education in Africa. In: Gillon and Gillon. *Op. cit.*, p. 63-7.

Emphasizes the importance of the scientific approach especially at the primary school level. The integrated science curriculum can contribute to helping students acquire this approach. Teacher training should be directed towards the continuous reconsideration of scientific knowledge and recent trends in science education.

Rutherford, J. and Gardner, M. Integrated science teaching. In: [269].

Discusses the philosophy of the unity of the universe. It suggests the importance of integrated science and how to select the content. Considerations to be taken into account when developing an integrated science programme are presented.

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Review of the progress in the teaching of integrated science in the Asian region and similar developments outside the region. The concept of integrated science teaching was presented, and suggestions for future action in curriculum planning and teacher education.

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DISSEMINATION OF INTEGRATED SCIENCE: OPPORTUNITIES AND CHALLENGES

Summary of working group paper by David Lockard

Dissemination of curricula from the countries which designed them often leads to adaptation, or at least adoption, elsewhere. Often the adapting or adopting countries have needs and circumstances similar to the designing countries; but sometimes they do not. The results could be disastrous were it not for the fact that science teachers tend to be innovative and to find creative ways of making the curriculum fit the needs of their students as they perceive them. Such modification should be of interest to the designers, and could provide cross-fertilization, but feedback is rare. Dr. Lockard then discussed some of the advantages of curriculum preparation as a co-operative exercise among people from various locales. At the same time, whole areas of the globe (for example, Europe and Latin America) have done little work in integrated science, and we should ask why this is so and if there is any prospect of their taking up integrated science education.

The International Clearinghouse has noticed that sometimes curriculum projects are taken up by very distant countries when the closest neighbours of the designing country have not used them. This raises interesting questions about the strategies of dissemination from the designing country and within the adopting/adapting country.

Adoption of a curriculum by a school system or national body has nothing to do with what goes on inside the classroom. More influential determinants of classroom learning are the teacher and the textbook that has been selected. This raises many questions about the training of teachers, pre-service and in-service, and communication to and from teachers, which is the essential dissemination.

Very often, especially in developing countries, dissemination of integrated science education runs into difficulties as a result of the conditions of service of teachers. Teachers are concerned with rewards - financial, status and self-image. When teachers are already comfortable

with an older curriculum, we should recognize and be sympathetic about the trauma caused by the demands of integrated science. Meanwhile, we are developing better understanding about the learning process as a result of the work of Piaget, Bloom, Ausubel, Bruner and Gagné, but it is not easy for the teacher without this kind of exposure to be understanding about, and sympathetic to, curriculum demands. It follows, then, that successful dissemination and implementation in a country are very much dependent on the level of training and awareness of the teachers. These are bound to vary from country to country.

Dissemination of integrated science as a concept, and as a classroom reality, is being achieved by a range of people from the teacher under the mango tree to Unesco. This range includes UNDP, the United Nations Environmental Programme (UNEP), the ICSU Committee on the Teaching of Science (ICSU/CTS), the national STAs, ICASE, and those who attend regional and international conferences. It also includes those involved in pre-service and in-service teacher training, training of science teacher educators, science inspectors and supervisors, teacher exchange programmes, some Unesco publications (such as the New Trends in Integrated Science Teaching series, the *New Unesco Sourcebook for Science Teaching* and the *Unesco Handbook for Science Teachers*) newsletters, booklets, flyers, textbooks and teachers guides, radio and television programmes, regional and international resource centres, consulting services, curriculum evaluation teams, workshops on the construction of inexpensive equipment, the British Council, the Council of Europe, USAID, the Organization of American States (OAS), the West African Examinations Council, GCE, the British Books Presentation Programme ... International dissemination is a matter of communication, not so much nation to nation as among all of us involved in integrated science education. It is difficult for any of us to claim that he is not affected by, or does not affect, the dissemination of integrated science education world-wide.

But we have to arrive at strategies of working together if we are to integrate anything.

OPPORTUNITIES FOR INTERNATIONAL CO-OPERATION IN THE DISSEMINATION OF INTEGRATED SCIENCE EDUCATION

Karl Frey

Towards an International Dissemination

Monodisciplinary science curricula have a certain universality which leads to fairly ready dissemination world-wide. There are also some internationally recognized curricula claiming to be integrated, but which merely co-ordinate knowledge from various fields (electrical conduction in nerves, for instance).

Truly integrated curricula, however, tend to have a local, or at most regional, character. They are usually related to the interests and experience of pupils. They may be built round topics and problems of local and regional importance, such as agriculture, sleeping sickness or diseases of civilization. Pure science may be woven in by relating together research methods and industrial production, scientific theories and technology, electronics and manufacturing processes, science's view of the world and the population's view, climatology and hurricanes or blizzards. Integrated science curricula tend to deal with matters of current or public interest. All these concerns are either not common to every country or have different degrees of importance in different countries.

Therefore curricula in integrated science are especially unsuitable for adoption. Adaptation and translation is another matter. There are two problems here. Firstly, the originators of the curriculum may be so concerned about accurate translation, to the extent that change for other circumstances becomes impossible. The second problem is the difficulty of getting to know the curricula in the first place. Local and regional curricula which may be of great interest as bases for adaptation elsewhere are known to non-specialists only through personal contact. The

International Clearinghouse Reports and other documentation are valuable to specialists, but the majority of scientists and educators have either not heard of them or do not know where to find them.

Nevertheless, there is a need for wide dissemination of information about local and regional integrated science curricula, so that workers in other countries and regions can use the experience of others when they come to develop new programmes. It would be unnecessary, indeed unwise, to translate and disseminate the curricula in their entirety. It would be much more useful to provide models, semi-concrete but at the same time of a general nature, in a number of languages. A model might consist of the basic structure of the curriculum, a skeletal framework, and a sample of individual units. From a collection of such models, a group could select and round out into a new curriculum appropriate to the new situation.

Towards an Increased Practicality

Much has been written in curricula and elsewhere about the desirability, feasibility and nature of integrated science teaching. Sometimes the preambles to curricula are not realized in the classroom materials; and often the statements are not concrete enough to be translated into practice by the teacher.

The concept of integration is not easy. Teacher training courses offer opportunities for the development of this concept, and some possible strategies in such courses are the reduction of content, reference to post-graduate interdisciplinary research, enrichment from the theory and the history of science, components which justify the subject matter, and involvement of the student-teachers in curriculum construction.

However, student-teachers and teachers in the field are faced with so many day-to-day problems that they need really practical help. Beyond the theory and philosophical statements, they need very detailed illustrations, either in a package (which could be expensive) or incorporated into the books of various kinds that teachers already use.

In some countries, those still in the exploratory stages in integrated science teaching, there is a special need for strategies which will help teachers to develop an understanding of what integrated science education is all about. Those countries and their teachers should not be left alone and lonely to work out their own solutions.

Different Emphases in Science in Different Countries

Those involved in the international dissemination of integrated science curricula should recognize that not all countries give the same emphases in science teaching. It is mainly in industrialized countries that teacher training at universities, where even primary teachers may receive their training, is based in the separate science disciplines. While these studies are set at the same standard as research, they do not stem from applied research. In content, they are only slightly simplified versions of diploma or Masters' courses in chemistry or physics. In countries like this, the teachers often form scientific associations (a physics society or a biology teachers organization, for example). Their aim is the spread of their particular kind of science at the standard of university science rather than for educational purposes. They are likely to be dominated by specialist university professors in, say, high energy physics. From these organizations come the writers of textbooks and syllabuses, and the curricula they design are disciplinary. If there is any interdisciplinary flavour, it is secondary and simply for the purpose of updating the knowledge; for example, some biochemistry has supplemented classical biology, and special mathematics courses are service courses for biology and chemistry.

In non-industrialized countries, science education is associated more with agriculture, health, nutrition, technology and the relationship between man and nature. It is in these countries that

we are more likely to find an integration of science teaching. Science is seen as being at the service of living standards, the appeasement of primary biological needs, and the evaluation and production of consumer goods. Traditional medicine and folklore about nature are recognized and incorporated into science courses. Various sectors of the population are exposed, through science, to better use of the earth, better nutrition, and the elimination of disease; and, in general, to a better life. (At the same time, there is still a tendency for the teachers to be organized according to the individual science disciplines, thus promoting these disciplines.)

In this dichotomy, international dissemination can cause problems. The disciplinary curricula of the industrial countries, having prestige, are being adopted by countries for which they are not appropriate. The converse is rarely true. There is thus a need for better balance in the exchange of science curricula among the various regions of the world.

A Proposal for an International Strategy for Analysis and Information

This proposal arose from the working group at the Nijmegen Conference. It was felt that knowledge and expertise about implementation of integrated science education was confined to only a few countries, regions and international bodies. We are especially lacking in information about mistakes, development problems and, above all, implementation problems. An individual country is not in a position to evaluate its own standing in integrated science education. When one is dealing with a whole country or a homogeneous region, international comparisons are needed. Only outsiders are able to make a critical analysis, since each country has its own structural weaknesses, stereotypes, self-concepts for certain roles, and organizational weaknesses.

It was felt that an international body in co-operation with a country or homogeneous region, could provide a relatively small group of analysts aided by one or two secretaries or research assistants. The group should consist partly of people well-acquainted with conditions in the country; but most of its members should be without detailed and up-to-date knowledge of these conditions, so that they bring to the analysis objectivity and the ability to be critical. They would study all available documents and carry out interviews, and their report would be published by the parent body.

The group would work within a framework applicable to most countries. This framework would face such questions as: are the curriculum materials in keeping with the educational policy of the country; is hardware and software in keeping with the educational policy of the country, and especially with good science education; is there a balance among research, development and teaching; are there structural elements in the educational system which hinder integrated science education; what is the relationship of resource centres; and does the country need international support of certain kinds? While working in close co-operation with all relevant local, national and regional bodies, the group must not be subject to their direction.

After a number of such analyses, the parent international body could develop (within a very loose and general framework) universal criteria which would lead to the systematic implementation of integrated science education under various conditions and towards various objectives.

In the first few years, the initiative for analysis should come from individual countries and regions. Whether in time it will be possible to cover all regions or countries one does not know; but the benefits to each country will be less, indeed it might be impossible for the group to function at all, if the country does not desire the analysis.

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See also [7, 33, 36, 114, 115, 118, 119, 151, 201, 205, 226, 268, 301, 311, 345].

DISSEMINATION OF INTEGRATED SCIENCE REGIONALLY AND INTERNATIONALLY

Working Group Report

Consideration of the authors' papers led to a discussion whose main features are outlined here in sequence.

Stages in Curriculum Change

An attempt to identify the stages in the curriculum change process led to the model shown in Figure 1. On this model, dissemination is regarded as a complex, often cyclical, process which

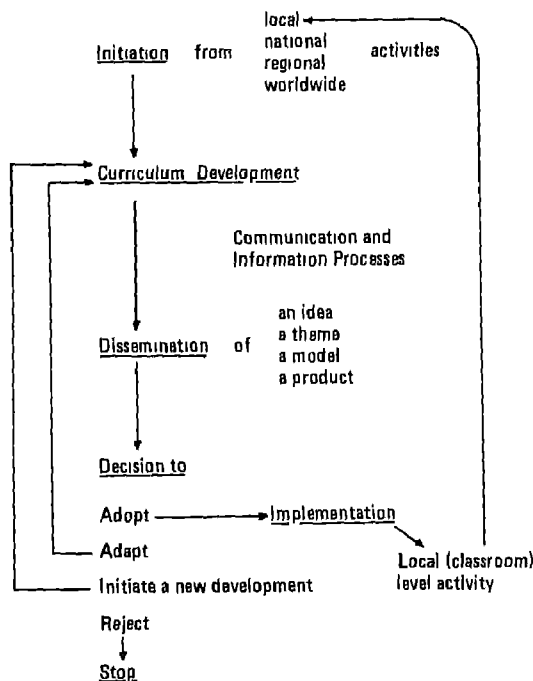


Figure 1. Curriculum Change Processes

comes before implementation, the latter being seen as essentially a classroom level activity. It was emphasized that, if the stage of 'reject and stop' is to be avoided, teacher involvement in all stages of the model is essential.

Implementation

This stage was then considered in some detail. A set of factors which could influence implementation was identified, as shown in Table 1. Although a glance at the table suggests few

Table 1: Factors influencing the process of implementation

Internal Factors		External Factors
Aids	confidence in the subject matter	pupil commitment
	commitment to the idea and philosophy	supportive colleagues
		time allocation
		rest of the curriculum
		support from education authorities
		support from education organizations
		support from parents
		acceptance by higher education
		job opportunities
		adequate teacher education and training
		adequate logistic support
		rewards (appreciation)
Hindrances	lack of confidence in the subject matter	examinations
		drop in status

hindrances, a closer look shows that converse statements about many of the aids would add to the list.

Some of the items in the table received further analysis. 'Rewards' would include some or all of the following types: affective, intellectual, professional, promotion, financial, access to further education and training, pupil success, and involvement in curriculum development and research. 'Logistics' includes matters discussed in more detail by Ferreyra's group, such as printed matter, laboratory facilities and equipment, audio-visual materials and technical assistance. 'Teacher education and training' received considerable emphasis. It is important to develop new, more adequate, patterns. Whether or not a teacher education course contains a strong monodisciplinary component, another essential component is some form of course in 'science', dealing with the major concepts and themes of science. The subject of teacher education has been dealt with by the group working with van der Cingel and Cheong, and it seems that there is considerable scope here for international co-operation.

Dissemination

The group was then in a position to work backwards from the factors affecting implementation to a parallel analysis of dissemination. Table 2 attempts to identify the level of dissemination which is principally affected by a given factor, and also to indicate the characteristics of the factors. It should then be easier to decide what areas would lend themselves to international or regional co-operation in a given set of circumstances. This analysis is now offered by the Working Group as an aid to decision making on matters of regional and international co-operation.

Explanatory Comment

Information Systems. While the group agreed that improved information systems are required, it was not agreed on whether or not integrated science needs new systems. One opinion expressed strongly was that it would be better to concentrate efforts on making existing systems better and more responsive.

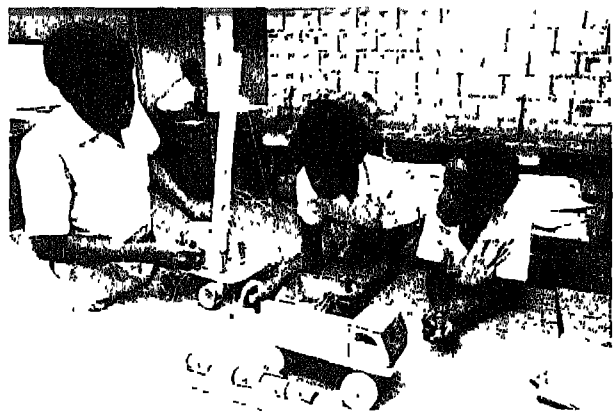
International Agencies. In recognizing the valuable role that international agencies could have, it was stressed that they must respond to local needs and should be more ready to develop a sensitivity to local attitudes. The 'selling' of ideas, themes, models and (especially) products was strongly opposed.

Co-operation. While some limitations are recognized, there are strong mechanistic reasons for regional and international co-operation. We can avoid a considerable amount of duplication of effort and replication of mistakes. Insights and experience can be shared. Against this, we have to set our belief that no curriculum is likely to be transferable entire from one country to another, so that it is at the model and local adaptation level, rather than in the product, that co-operation can have value. Regional co-operation would be especially useful in the development of programmes for teacher education. However, successful co-operation depends on more than a desire for co-operative development of new school curricula, there must also exist 'regionality' and a desire for association. And a regional activity must be treated as a complement to, rather than a substitute for, local activity.

Regional and International Co-operation, and the Classroom. In all the discussions, the need for visible impact at classroom level was stressed. It is difficult for external agencies to operate down to classroom level, but as few intermediate stages (or obstacles) as possible should be put between the teacher and the information and resources he requires.



From Scottish Integrated Science ...



... to West Indies Science Curriculum

Table 2: Factors affecting dissemination

Factor	Level of effect	Characteristics
<u>Aids</u>		
Person to person contact	ideas, themes	mechanisms
Information systems		
- accessible resource collections		
- international newsletters		
- publishers' propaganda		
Provision of financial, physical and human resources	models, products	
Supply objective analysis of problems and evaluation of products		
Accessibility to decision making authorities	ideas, themes	foci
Strong professional associations of science teachers	models, products?	
Wish to participate in international development of philosophy and strategy for science education development	ideas, themes	attitudes
Understanding of degree of advance in the curriculum model or materials	models, products	
Adaptability to match local characteristics		
Receptivity to innovation and attitudes to change (for whatever purpose)	ideas, themes	
Prestige value of association with international bodies	?	
<u>Neutral</u>		
Degree of centralization of the education system		mechanisms, foci, attitudes
<u>Handrances</u>		
Differences in educational systems		mechanisms
Structures and assessment patterns	models, products	
Level of teacher competence and performance		
Level of sophistication of curriculum model and materials		
Language barriers (variable)		
Non-availability of required materials		
Vested interests in preserving status quo	models, products	attitudes
Existing value systems and prejudices (there must be a dissatisfaction with what exists, as a motivation for innovation and change)	ideas, themes	

20. Interaction of science and society: consequences for education

J. C. Terlouw

Summary of plenary paper

Man in his history has been influenced by a myriad diversity of people and events, but nothing in the world has had such a fundamental, such an irreversible and such a rapidly expanding influence as the development of the physical sciences. These and the related technical sciences have completely changed the face of the whole world in a few hundred years, and they may even be an immediate threat to the survival of the human species.

Science and technology should of course be the servant of man, but through unsound decision-making it is often the master, and we are not sufficiently aware of its power. However, people are becoming aware of the need for a critical attitude, and there is more and more discussion about *Interaction of Science and Society*, particularly by those associations devoted to science and technology.

MAN'S DEPENDENCE ON TECHNOLOGY

Of course, man and technology are fundamentally interconnected, but man seems to have become the slave of his own ability. As with any species, the size of the human population depends on the availability of food. Population growth has accelerated with the development of agriculture; the domestication of animals, changes in environmental planning policies, the discovery of new continents and emigration to them, fertilization by minerals, mechanization, pesticides and irrigation have all been followed by a dramatic reduction in the time taken by the population to double itself, from 1 000 years to 200 years to forty-five years. Medicine and improvements in hygiene have done their share. And there we have the dilemma. Who would dare to have the masses perish by abolishing technology?

One might say that the nuclear bomb is an acquisition with which man defends himself against that which threatens his existence; the reality is that, if anything threatens the existence of man, it is nuclear weapons. It is true that their use is dictated by politics, but before that there was the scientific dictate, and the physicists who developed the atom bomb knew very well what they were doing.

We know that with our methods of production, we contaminate the environment, yet we can tackle the problem only very slowly because otherwise the economy and life as we know it would collapse. Science and technology resemble the magician's apprentice; they are difficult to hold back and

we have become too dependent on them.

THE ONE-SIDEDNESS OF SCIENCE AND TECHNOLOGY

Our knowledge is great but one-sided. We can transmit television pictures, go from the Netherlands to New York in six hours and use computers to perform calculations at lightning speed; but we cannot restore a squashed midge to life or reproduce the transformations that take place in every green leaf. We know precious little about the simplest organism, much less about the processes in human society. We cannot prevent wars breaking out and we do not know what to do about unemployment. Technical development has brought us prosperity, comfort, bread and circuses; but we often forget that technology is limited and one-sided.

THE INFLUENCE OF SCIENCE AND TECHNOLOGY ON ETHICS

Our attitudes to sex are influenced by the Pill, space travel reduced the infinite heaven to a human level, television brought the ridiculing of values, once thought unalterable, into the living room. Such technical developments do broaden one's horizon and stimulate ethical developments, but we should be aware that our attitudes are changing. To my mind there is a 'law of conservation of faith' whereby faith abandoning the church re-emerges elsewhere, so I do not hold the view that scientific developments dictate ethical developments, but they do have a strong influence. In theory, everybody admits that man should be central, not science, but many people have become lonely behind their electrically operated doors in monstrous blocks of flats, unable to see the changing of the seasons.. One sometimes wonders whether the human being is the measure of all things in this technocracy.

DECISION-MAKING IN SOCIETY

The decision-making procedures in society are inadequate. In our industrial society, experts are a characteristic phenomenon, but who can call himself an expert in policy decisions which are likely to have long-term outcomes? In the years since the war there has been much progress of a kind. Old age pensioners are taken care of until their death in neat little rooms, provided with a television set in a communal room, there are tidy blocks of 60 to 160 flats, each with its balcony for the pram, and separated by planned strips of green (the partition walls are rather thin and the power of the amplifiers has increased, but one gets used to it); we can buy cars and go on package tours to Mallorca. But no heed has been paid to the fact that, rather suddenly, it is no longer possible to swim in open water; in perfecting technocracy, scarcely anyone has asked people whether they really wanted things this way. I am often expected to give an expert opinion on a problem intimately related to physics, as for instance the energy problem. When physicists cannot even understand each other's publications, how could you have faith in the expert advice of a physicist when a problem concerns not only joules and watts but also population, environmental planning, consumption patterns, genetic effects and what have you? My training as a physical scientist helps me to gather facts, to understand them, perhaps also to present the relevant arguments clearly, to be objective, to think logically, to distinguish between false and true arguments. But in the end, this training will not be of any use when political decisions have to be taken, for they are based on convictions.

While it is the responsibility of the politicians to take decisions and to develop society, the practitioners of science and technology should not shirk their responsibility of recognizing tendencies and fighting them. At the same time we should consult those for whom the application is intended and those who will experience its drawbacks.

CONSEQUENCES FOR EDUCATION

It is the scientists who are equipped with the necessary knowledge for decision making and no one else. Therefore awareness of the consequences of scientific research should be an essential part of their training. But who is to teach the social consequences of research? Science does not have methods to question itself. However, the teaching of science as a human and therefore social activity should, I believe, be done by the science teacher and not by the philosophers or social scientists. The teacher should be a person who has thoroughly investigated the essence of science itself. And if science teachers cannot or are not allowed to discuss the consequences of their subject with their pupils, we have a case of narrow-mindedness on our hands on the part of someone. Again, to separate philosophical and political ideas about the consequences of science from the results of research is to run the serious risk of influencing these results themselves, something we must never allow to happen, a lesson we learnt hundreds of years ago.

I conclude therefore that it is no longer admissible to practise or to teach physical science without taking into consideration the profound consequences of science and technology for human society, for the world and for the future. This must be an integral part of science teaching. Tertiary education institutions will have to provide the science teacher with the knowledge and motivation he needs. Just as the pharmacist is taught about poisons and concern for his client, so should other scientists be taught about drawbacks of our technical attainments and of the instruments of our welfare state.

Great thinkers in the history of man have given us a structure of incomparable beauty, a joy to study and a joy to pass on. But scientists have up to now looked more to the beauty of the structure than to anything else. We should know better by now. Technology is part of man and the influences of science and technology are enormous, at first especially on western cultures but now on the whole world. But they only modestly contribute to human happiness where they could contribute considerably. We must try to bring about a change in mentality, in human nature, through education.

Wherever knowledge increases responsibility increases. He who teaches young people probably shapes the future more than anybody else. Certainly he who is aware of the problems and at the same time teaches young people bears a very heavy responsibility.

The full text of this paper (12 pages) is available from the author.



An undersea complex of communities - insight into their future?

21. Science in society

John Lewis

One of the stated aims of *New Trends in Integrated Science Teaching* is to stimulate innovation. It is the aim of this paper to indicate a direction in which science teaching ought perhaps to be moving.

The major problems of the world centre around energy, mineral resources, population, resources of land and water, food and agriculture, health, the role of industry and, of course, poverty and the quality of life. These are the issues which will dominate the lives of the children we are now educating, whether those children be in developing countries or in more sophisticated communities. All these themes have a strong scientific component and a greater awareness of them should be included in the science education we provide for young people.

This presents a challenge. It involves much more than integration of physics, chemistry and biology. We need to involve the physicists, the chemists and the biologists, but also the geologists, the economists, the mining engineers, the historians, the geographers and of course the engineers and industrialists. There is scope here for integration of a kind we have done little about in the past.

TRENDS

Trends in science education in the last twenty years have centred around personal involvement by the pupil. Before the curriculum reform projects initiated in the United States in the late 1950s, the emphasis in science teaching was on the acquisition of factual knowledge. Then came PSSC, CHEMStudy, CBA and BSCS in the United States, followed by the Nuffield Projects in the United Kingdom, and then a wealth of other projects around the world. As well as pupil involvement, these curricula strived to replace rote memory by understanding of fundamental principles. Pupils were to collect evidence from which they could establish patterns and thence arrive at fundamental laws, the experiments being skilfully devised so that the evidence was there to collect. The aim of many of these projects was to give the pupil the opportunity to be 'a scientist-for-the-day', to experience how a scientist looks for evidence, how he tests his hypotheses, how he looks for patterns in the phenomena around him, and it dominated curriculum reform until the early 1970s.

By then, certain projects had come to realize that searching for fundamental laws did not meet all needs. The projects of the 50s and 60s had a profound influence on teaching methods and the kind of teaching that they promoted is still upheld as a standard. A somewhat paradoxical influence was a growing awareness that these very projects were looking too much inward on science; in the effort to show that science made sense, the relevance of that science to the world outside

the classroom was being overlooked. The East African Secondary Science Project, although using many of the Nuffield ideas, considered that discussion of wave-particle duality was less relevant to its pupils than some awareness of statics applied to building their own houses. It is true that some projects stated an intent to promote awareness of social problems, but few projects succeeded in this, usually because of the wealth of pure science that it was felt necessary to include.

The developments in science curriculum might be represented by Figure 1, first suggested by Norman Booth. The curricula just discussed, those concerned with *pure science*, are represented

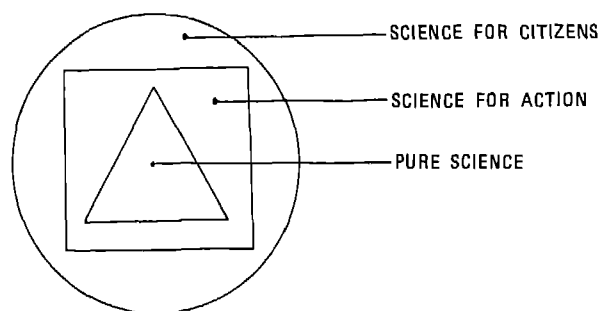


Figure 1. Components of science teaching

by the triangle. But how much does one bank a road going round a corner? The answer to that does not lie inside the triangle, the Newtonian analysis of circular motion does not provide it. We learn about conduction, convection and radiation inside the triangle, but not where to put a convector heater in a room. There is a world outside that triangle represented by the square and which we call *science for action*. But there is more to science than that. In democratic countries, citizens will have to make decisions which will intimately affect their lives, and many of these decisions will have a strong scientific component. Preparation for this kind of decision making lies inside the circle, which we call *science for citizens*.

NEEDS

Therefore, while the curriculum reform projects have done a magnificent job by getting students to think for themselves and to come to a better understanding of their science, there is a growing feeling that we must make it clear that this thing we call science is relevant to the society in which we live.

There has been a tendency in some countries for students to turn away from science. They associate physics with the bomb, chemistry with pollution and biology with biological warfare and genetic engineering. The blame for this must lie very heavily with those of us who have been introducing science to those students: we have failed to show its relevance in the world in which those students will live. Baez and Alles have referred to compassion [270]. That is a term which might be useful in this context. Many young people are idealistic and caring people and one of the many reasons why they are moving towards law, medicine and the social sciences may be because they are interested in people, and perhaps one of our faults is that we have failed to bring Man into our science teaching, above all into physics. One participant at the Nijmegen conference urged repeatedly and forcibly that Man must be at the centre of our teaching, what he called an *anthropic*

approach. It might be appropriate to remember Einstein's comment:

'Concern for the man himself and his fate must always form the chief interest of all technical endeavours. Never forget this in the midst of your diagrams and equations'.

In making this plea for relevance, we should not forget that much depends on the age group that is being taught. The 10-11 year old pupil is not concerned with world problems. For him society means his home and his immediate environment and the science teaching should be relevant to that. As he grows older, his view of society can gradually enlarge to embrace his community and his nation. It is probably at the 16-17 year old stage that he can be awakened to world problems. Even if he does not continue his study of science, he and his contemporaries will become a gradually better informed public which could ensure a satisfactory future for Mankind.

At a Unesco *ad hoc* meeting of experts on science education in July 1977 the unanimous view of those present, representing all regions of the world, was that science teaching must be made more relevant and it must reflect more of those issues concerned with *science in society*. Again, a regional conference in Penang in 1977 stressed the need for science education to be more closely linked with the needs of society. And there are many more examples of similar resolutions passed at recent conferences.

WHAT IS ALREADY BEING DONE?

The formal appearance of courses and curricula called 'Science and Society' is relatively new. Programmes began to appear in the early 1970s in universities, especially in the United States and the United Kingdom, often under the auspices of departments of political science or social science, sometimes in schools of technology. A recent survey (1972) by the sub-committee on Science, Research and Development of the US House of Representatives has shown that the number is increasing substantially, though not yet frequently in association with departments of natural sciences [422].

Ezra Heitowitt of Cornell University reported at the Joint Symposium of the American Association of Physics Teachers and the American Physical Society Forum on Physics and Society on 116 formal academic programmes concerned with science policy activity. A Unesco survey in the area of science policy identified 344 units active in this field in twenty-six European and North American countries [435].

It was reported by Fowler [111] that in 1973 there were 166 courses in the United States under the heading 'Physics and Society', though these were categorized as 'courses for non-scientists'. Typical amongst them is that developed by Dietrich Schroeder at the University of North Carolina [433]. In the United Kingdom there are many university courses available on the history and philosophy of science, environmental science courses, and courses on energy and energy technology which incorporate many social aspects. A co-operative programme by several British universities has led to the development of the SISCO material (Science in a Social Context). In Swedish universities, an increasing number of science courses have a 'science and society' component. In the Netherlands, many universities require students to spend 5 to 10 percent of their time on the interaction of science and society. An interesting development in recent years is the Open University in the United Kingdom. Their Science Foundation course is very much concerned with aspects of science and society.

But the activity listed above is all at the university level and very much less has yet been undertaken at the school level.

In the United States, there is the Man Made World developed by Engineering Concepts Curriculum Project (ECCP). More recently in the United States work on Energy has been undertaken by the National Science Teachers' Association under the direction of Dr. J.M. Fowler and this has strong Science and Society components. In the United Kingdom SCISP is intended for pupils aged 13 - 16 and has a strong social component. CROASE is working on the production of a curriculum for the

same age range and with the same characteristics. New Zealand's Modular Science, although not fully integrated, is similar.

In 1977, the Association for Science Education undertook a new project called *Science in Society*. The British system is very much dominated by examinations and this new curriculum project aims at developing a one year course suitable for 16 - 17 year old students with a GCE examination at the end. The long-term aim of the project, however, is not to provide yet another examination, but to help science teachers in secondary schools - most of whom are graduates in pure science - to appreciate more fully the relevance of science, so that in turn they can show that relevance to younger pupils through their teaching.

In Sweden a course is provided through Television and Radio Education in Schools (TRUAS) which shows the interaction of science and society. Norway has a comprehensive programme for its schools and reference to the environment is amongst the topics that must be taught.

Two science programmes in Australia deal with social implications: ASEP for 11 - 16 year old pupils and the Higher School Certificate Physical Science course for 17 - 18 year old pupils, developed at Monash University.

In India, two projects involve social aspects: Learning Science, An Integrated Science Curriculum, for 11 - 13 year old pupils, and Science and Society, an integration of science, language and society for 16 - 18 year old students in Indian Schools. Both these were developed at NCERT, New Delhi.

In the United States, the Educational Development Center (EDC) has developed a unit for senior high school students on Energy, People and Their Environment, and BSCS has developed material on problems of society for which biology has both information and a message, such as birth control, misuses of natural resources, effects of drugs, etc.

Although the number of programmes for school use are few at the moment, the demand - from all regions of the world - that science teaching in schools should show greater relevance to society will undoubtedly mean that considerably greater attention will be given to it in the future. It is now reported, for example, that the National Science Foundation in the United States has recently set aside 1.5 million dollars to develop a Science and Society course 'as a matter of urgency'.

NATURE OF A SCIENCE-IN-SOCIETY COMPONENT IN SCIENCE COURSES

We must never forget that science and engineering are dependent on certain basic concepts - and we must be careful not to produce a generation of young people who can talk about science without having understanding of those basic concepts. Our future scientists and engineers have got to have knowledge of basic scientific principles. The working group at the Nijmegen conference advocated three components of science courses: concepts, processes, and social aspects of science and its applications. The need now is to be more specific on what are the issues which should be included in our programmes.

Aims

To understand the nature and limitations of scientific knowledge. Pupils should appreciate that scientific knowledge is the result of Man's purposeful activity and is continuously evolving, and is not a static, immutable set of facts, laws and theories; that scientific predictions are based on this tentative scientific knowledge and, therefore, also include uncertainty. The limitations of science, both intrinsic (for example, thermodynamics) and philosophical (the inadequacy of science on its own to solve problems of society) should be emphasized, as well as the power of science and the contribution which it has made to raising man's expectations and improving the

quality of life.

To appreciate that the use of scientific knowledge can be both beneficial and detrimental to society and the environment. Pupils should appreciate that the applications of scientific knowledge in agriculture, industry, medicine, etc. can lead to a raising of the standard of living and a change in the quality of life. They should appreciate that particular applications of scientific knowledge may lead to both beneficial effects (such as the development of new materials and an improvement in health standards) and detrimental effects (such as the pollution of the environment or upsetting a farming community to build a factory or a motorway. Pupils should obtain a realistic picture of the scientist working in society and especially the kinds of constraints which affect his contribution to society.

To appreciate that the Earth's resources are finite. Pupils should appreciate the problems associated with rapid (often exponential) increase in the use of finite resources and the need for conserving and recycling these resources. This should lead to the idea that Man must be a responsible 'tenant' of the Earth and have a consideration for the needs of all human communities, present and future.

To understand the need for, and to develop, the ability to make reasoned decisions which take account of relevant constraints. To recognise that moral considerations are involved in decision-making. Pupils should appreciate that individually and corporately, Man is constantly confronted with the necessity to make decisions about widely differing issues (such as the provision of energy and food in the future and the siting of industry). They should appreciate that technology involves a consideration of aesthetic, ecological, economic, moral, political, scientific and social factors, as well as applied science. A pupil should recognize his responsibility as an individual to 'do something about it' and not to lapse into the adult tendency to stay out of trouble, merely wringing one's hands about *Them*. This is something to do with self-respect and courage and selflessness.

Content

I should stress again that it is necessary for young people to learn science, and we hope that the methods adopted will encourage the maximum understanding; there is still a very important place for *science for the enquiring mind*. The topics listed below should therefore be thought of as supplementing existing material rather than replacing it, showing the relevance of science to the society in which young people will grow up. Inevitably there will be differences in content depending on the country concerned, but as many of the problems are world-wide issues, it is possible to make some generalizations.

Energy, for example, is as much a concern for India, Indonesia or Israel as it is for Belgium, Barbados or Botswana. It is necessary to give some feeling for the concept, followed by some appreciation of the world's problems concerning future energy resources. There is no need to stress in this paper that oil resources are finite and the problem of alternative energy resources is a matter of which all world citizens should be aware. It is good that young people should learn about radioactivity, but we need also to concern ourselves with what is involved in nuclear power stations. Decisions have to be made (there is the question of breeder reactors, for example), decisions that have to be made through an informed public, and that is where the science educator has responsibilities.

School courses have long been concerned with iron and steel, but very little attention has been given to the mundane mineral resources - the gravel, the sandstone, the limestone and so on, which we all take for granted. The part that minerals play in the economy of each and every country, the effect on the environment of mining activities, the need for recycling of our limited resources: these are issues which might have a place in such a course. The lessons to be learnt from the Club of Rome's *Limits to Growth* - whether one accepts or refuses the details of the report - remind us that we cannot indefinitely have exponential growth in a finite world.

It is perhaps unfortunate that physics teaching has been concerned with exponential decay (Ae^{-bt}) - the discharge of a capacitor, the decay of a radioactive substance - when the world problems are all concerned with exponential growth (Ae^{bt}). Nowhere is this more apparent than in the problems of population. There is no greater problem than this and of course it is not just a matter of birth rate and death rate, but a complex problem concerning age distribution. The hope for the future lies in education and awareness of the problem must come through our teaching. This is a human problem, not just a biological one and it ought to be in our courses.

There are issues concerning resources of land and water, very real problems for many countries. Here is scope for integrating our science teaching with that of the geographers and the economists. And that leads naturally to problems of food and agriculture. If the exponentially increasing population is ever to be fed, the solution can only come through science and technology - and that means education as a preliminary stage so that people are aware of what is involved. Reference should also be made to medicine and the trends which are now becoming apparent in various parts of the world.

Links with mathematics are also important. People are subjected these days to statistics and to graphs of all kinds, and a wider appreciation of their significance could be relevant to our courses. Communications and data handling are other topics of which students should be aware.

At some stage of the course, it would be appropriate to give some attention to the problems associated with information. This might involve certain philosophical aspects: what is meant by *facts*, what are *value judgements*, the difference between *observed* and *inferred facts*, the nature of *laws* and how they differ from *hypotheses*.

Some history of science and technology might be appropriate, showing how they have developed against social background: how the Mediaeval Schoolmen brought together the work of the Greek scientists and the Christian bible, how 'science' at that time was based on authority, the changes brought about by the Renaissance which began to question authority, how experiment became more and more an accepted part of science, the coming of the Age of Reason and the influence of Newton, and then the impact of the industrial revolution and its consequences for all parts of the world. The conflicts over the Copernican revolution or Darwin's theory of evolution should be seen not as a conflict between science and religion, but a conflict with authority. The changes that have come over science in the last hundred years deserve mention, how the confidence of the scientists of the later part of the nineteenth century gave way to a humbler attitude, to a realization that we do not know all the answers and that many of our models about the fundamental nature of matter are only models to be replaced no doubt by further models as our understanding increases.

We must remember that a high proportion of our science students will find employment in engineering and in industry. Industry is the means of producing purchasing power and is essential to the economy of all our countries. Ought we perhaps to be showing, more than in the past, the role that industry plays and how the science we teach is essential to it?

Finally, some place should be found for the problems of poverty and what is meant by the quality of life and the importance of human relationships.

Of course a different emphasis will doubtless be placed in different countries, but it was significant that there was unanimity in the working group at the Nijmegen conference that the themes outlined above were those which ought to have a place in science education in the future.

TEACHING

Here lies the real challenge. At university level, there is less difficulty, but in the school situation this kind of work is new for the science teacher and much effort needs to be put into it. The danger lies in the teacher merely imparting factual knowledge without the student feeling personally involved. We have to move away from the convergent thinking of the past in order to

move into the divergent thinking that is necessary. But techniques are being developed - the use of project work and decision-making simulation games, for example - which open up possibilities, and doubtless other ways will be found. The working group at the Nijmegen Conference stressed the need for opportunities in the future at which there could be an interchange of views on methods of teaching this material.

CONCLUSIONS

In his chapter, Showalter presents an (explicitly) one-sided case for the unified teaching of science, and there appears to be almost unanimity that science teaching up to the age of about 12 should be integrated. However, for older children these arguments are not convincing enough, as Showalter would probably readily concede, since many of the aims he lists can be achieved through the study of separate disciplines, as Booth also says in his chapter. I do, however, believe strongly that our teaching should be seen to be relevant to the needs of society, whether these are local or world-wide, and this belief is repeatedly expressed throughout this volume by the participants at the Nijmegen Conference. Our teaching should be more concerned than it is now with the wider issues of energy, of resources, of population, of health and medicine, of food, nutrition and agriculture, of the role of industry, of poverty and the quality of life. And these concerns cannot adequately be considered within the confines of physics and chemistry and biology, even if a child were to learn all three. All these disciplines have much to contribute to the teaching, but so have geographers, economists, engineers, geologists, home economists, historians. It is through consideration of the content of the course and the needs of society that we come to see the need for a greater degree of integration than has been possible in the past.

This paper has attempted to suggest that perhaps our science teaching in the past has been too inward looking and that we ought to be taking a wider look at our science, not just by integrating the basic sciences into a unity, but integrating them with wider issues in order to show the relevance of our teaching to all that goes on outside the classroom. In this way, one hopes that students will come to see that science and technology can contribute to solving the real problems of the world, and that they themselves can have a part to play in finding those solutions.



Alternative energy sources

22. Science education for society

Robert Silber

This paper was not discussed at the Conference, and it is therefore a personal statement by the author.

World society today is a delicate balance of co-operation and interdependence. Not only has man developed the means to destroy himself and almost everything else on earth by nuclear holocaust, but mankind faces other problems vitally relevant to the existence of life on earth. Such unsolved social problems in many parts of the earth include feeding people, providing for better health, designing adequate shelter, releasing people from physically exhausting work, and producing a livable overall environment. If these problems are to be understood and solved, education must assume a major rôle. In particular, science education has new responsibilities to bring a message to the people of the earth. This will require the combined commitment and co-operation of the best minds among educators, scientists, technologists and members of government at both national and international levels.

INTERNATIONAL CO-OPERATION IN SCIENCE AND TECHNOLOGY

Science and resultant technology have made great contributions in such fields as transport, space exploration, food production, building construction and the fight against disease. A Green Revolution has been produced (in some countries) by new strains of wheat and better fertilizers. Smooth air travel has shrivelled the world. As D'Ambrosio has pointed out in his chapter, we can quantify and process information in new ways, and therefore solve problems that used to be insoluble.

However, science and technology with their new achievements have acquired new responsibilities. At the Bellagio Conference on Science, Technology and Society, Thomas F. Mallone put it this way.

'The Bellagio message is at the same time an affirmation of faith in the fundamental goodness of humankind, and a sobering assessment of the dangers that must be avoided in order to attain a better future for everyone. It is also a moving appeal to all scientists to join forces with engineers, ordinary citizens, and decision-makers, in order to address the world problems in a spirit of international co-operation.' [244].

While the Bellagio Conference identified major world problems, considered the rôle of science and technology in alleviating these, and stressed the need for co-operation among all humankind, it was also noted that there are serious political, economic and social constraints. Application of technology on a large scale is accompanied by lack of knowledge about it; and the environmental

impact crosses national boundaries, requiring a spirit of co-operation among nations which we have not as yet achieved [244].

We should, however, be encouraged by some international activities which attempt to attack global problems relating to science and technology. Environmental scientists have joined in exchanging data and methodology in, for example, the International Biological Program, the International Hydrological Decade and the Unesco Man and Biosphere Programme. Another means by which scientists from all countries can work on global problems is ICSU, one of the supporters of the Nijmegen Conference. ICSU provides a machinery for co-operation among such inter-governmental bodies as FAO, UNEP, the World Meteorological Organization (WMO), WHO and Unesco, and its Scientific Committee on Problems of the Environment (SCOPE) was established to improve knowledge of the influence of human activities upon the environment, and of the consequences for human health and welfare of the resulting changes. In a recent report recommending actions in preparation for the future, SCOPE identified a need for a more considered approach to environmental education. [291].

Although the key to a livable, healthy future seems to lie in shared planning, Eckholm has pointed out that foreign aid projects and indigenous development programmes alike too often fail to discern and eradicate the ecological roots of impoverishment [381]. If this is so, and I believe it is, then it looks as if we need new strategies aimed at the people who will work in the projects and programmes and the people who will be affected by them. In short, it appears that we should prepare young people while they are captive in school.

OPPORTUNITIES IN SCIENCE EDUCATION

If problems of energy, environment, food, population and so on are to be solved, then the population as a whole must understand the problems. That is the rôle of education. But education itself is caught up in the same problems. Brown and co-workers have pointed out that rapid population growth, itself aggravating lack of educational facilities, leads to increased social inequality. Meanwhile, poverty, large family size and closely spaced pregnancies hamper the development of children's cognitive, verbal and motivational capacities as well as their health and physical development [369]. Hence countries suffering most from food shortage, health deficiency and environmental misuse are also those that can least afford adequate education while, ironically, education is the medium that offers the best chance for the country to solve its most basic needs.

As science and technology can make a major contribution towards solving these societal problems, so is science education a vitally important part of the school curriculum. If students are to be prepared for the future and for national development, there must be attention to such issues as drugs, population control, energy conservation and pollution. Serving as foundations for an understanding of these issues, there must be teaching of the basic concepts of science. And the science curriculum must reflect the technological direction of the country.

Of these three components, it is reasonable to leave the identification of scientific concepts in the hands of the science educators. However, societal and technological issues and goals are matters that should be identified by national leaders - government planners, scientists, engineers and economists as well as educators. Once the issues and goals have been identified, it is up to science teachers and others to reflect them in their teaching. It is difficult to see how they can be reflected unless there is at least some integration, not only of the sciences but also with other disciplines, especially with social science.

SCIENCE EDUCATION FOR WHOM?

Scientists and technologists are needed, of course, as a most important element in the country's manpower bank. But preparation for these careers has traditionally dominated science education,

even if perhaps courses have often fallen short of direct involvement of the children in a scientific way, and if the technological component has been limited. Here is a goal that is recognized everywhere; all that is needed are better ways of achieving it.

As society becomes more and more technically oriented, education must play its part in preparing people to perform technical tasks. Some countries already have specific technician training programmes. The Tenth Clearinghouse Report [201] shows that over the last twenty years, some forty-five major curriculum projects in seven countries have developed materials and courses related to scientific technology; and thirteen of these in six countries were currently active in 1977.

However, all children will grow into adults in society and will have to face societal problems. All children need an education in science. This is a goal that has not yet been properly recognized, and perhaps this is because science educators have not conveyed to the decision makers what education in science can do. We can give tomorrow's adult a basic knowledge about the natural world, an understanding of the methods of scientific investigation (especially of the relationship between theory and evidence), an appreciation of the limits of scientific inquiry, and some knowledge of the ways in which scientific research can be used to improve daily life; we can also give him an awareness of social and moral problems that may arise from the research, and we can help him develop a set of values and the ability to make decisions. In short, without an education in science for all, there is no hope of a scientifically literate public able to use evidence in arriving at sound decisions about societal issues. We have somehow to help people understand this.

RECOMMENDATIONS

I should like to suggest some actions that would help to provide a better science education for society, both by conveying to decision makers that the need exists, is indeed urgent, and by giving science educators the opportunity to identify how they can best fill the need.

Dialogue between science and science education. Scientists can learn about the aims, methods and problems of teaching science, and can use some of the strategies in transmitting science to the public. Science educators can learn about the cutting edge of science and technology, its methods, achievements and problems, and thus provide courses which reflect science and technology as they are in the late twentieth century in the particular country. This sort of dialogue can be achieved by conferences, workshops, and co-operation in the development of materials for children and the public.

Dialogue between government and science education. Science educators must convince their government of the need to provide support, and identify the areas in which they need help, financial and in other aspects requiring government decisions. The most effective liaison would be through an active science teachers' association.

Dialogue between teachers of science and of other disciplines. With the new trends towards integrated science, environmental education and education in societal problems, science teachers need the expertise of other teachers. The new kinds of science teaching also require co-ordination with other courses, so the science teachers must give their colleagues some insight into the science courses. D'Ambrosio's chapter in this book deals with this issue at some length.

National discussions on technological futures and science education. If there is to be planning for the future, then representatives of government must obviously get together with scientists, engineers, economists and sociologists. What is less obvious to these groups is that the plans must include education in general and science education in particular, and that educators should participate in the discussions. Perhaps it is up to the science educators to initiate a national conference.

International exchange of information and ideas. Although the situation in each country is unique, societies, problems and professions are largely interdependent. It is surely unnecessary to spell out the value of international sharing to anyone who attended the Nijmegen Conference or has read this report.

We have never before had so many opportunities for constructive effort world-wide, nor so much awareness of the need for it. Using the best minds in all countries, we must strive through science, technology and science education to protect society against itself. There are no other options.

FURTHER READING

Maybury, R.H. *Science Education: Technical Assistance and Innovation in Science Education*. New York: Wiley, 1975. 210 p.

CHEMISTRY OF WINE MAKING.

FRUIT SUPPLIES FLAVOUR AND WILD YEASTS. SUGAR IS THE SUBSTRATE WHICH IS CONVERTED TO GLUCOSE.

$$C_{12}H_{22}O_{11} + H_2O \longrightarrow C_6H_{12}O_6 + C_6H_{12}O_6$$

 SUCROSE INVERTASE GLUCOSE FRUCTOSE.
 GLUCOSE AND FRUCTOSE ARE USED IN ANAEROBIC RESPIRATION OF THE YEASTS.

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2 + \text{ENERGY}$$

 ZYMOSE ETHANOL.

THE SODIUM METABISULPHITE TABLET RELEASES SO_2 PREVENTION WHICH DESTROYS ALL -

MICRO ORGANISMS EXCEPT THE ANAEROBIC YEASTS AS THE ALCOHOL LEVEL RISES THE YEASTS ARE DESTROYED.

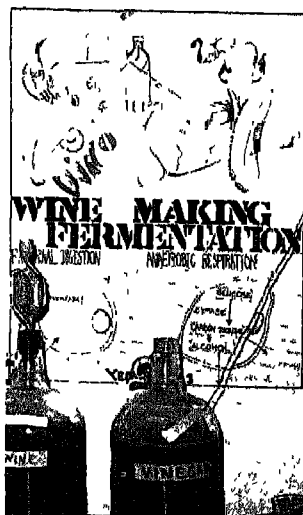


VINEGAR

A PRODUCT OF AN AEROBIC RESPIRATION IN CERTAIN STRAINS OF YEAST. PROCESS: SUGAR SOLUTION FERMENTATION. POLYCARBONIC (A WEAK SOLUTION OF ETHANOLIC ACID IS VINEGAR).



Metals in Australia



DISTILLATION

EXTRACTION OF RAY-OIL. PROCEDURE: 1. WASH OUT AND CRUSH RAY LEAVES. 2. PLACE IN DISTILLATION FLASK, ATTACH CONDENSER.

3. HEAT. 4. FRACTION 1. MILKY FILTRATE COLLECTED SHOWING A MIXTURE OF RAYOL AND WATER. 5. HEATING WAS CONTINUED UNTIL CLEAR FILTRATE COLLECTED. THIS WAS WATER. 6. SEPARATION OF DROPLETS OF RAYOL FROM THE WATER. 7. DISTILLATION. 8. DISTILLATION - CONTINUOUS. 9. RAYOL OIL FROM.



Teacher preparation in Israel

Natural products in the West Indies

23. An educator's view of the Nijmegen Conference

Judith Reay

Abstract of plenary address

Coming as it did a decade after the Varna Congress and half a decade after the Maryland Conference, the Nijmegen Conference on Integrated Science Education Worldwide was a significant landmark in our profession. It had to be. But a question that exercised every participant was 'Have this conference and its predecessors done any good, and will we as professionals adopt wiser practices in future?'

At the conference, all participants were reflecting on the preceding ten years, sharing their experiences, and looking ahead. If it had been possible at the end of the conference to identify really concrete outcomes of Nijmegen, we should have been working at a superficial level. It is an educational principle that learning takes time, that material must be gradually absorbed into the cognitive structure of the learner and to become an integral part of him. Big understandings grow slowly, and it seems to me that the discussions of Varna and Maryland are only now becoming coherent; and I expect the exchanges at Nijmegen to crystallize only after several years.

Integrated science is a concept that has been slowly taking root in the cognitive structure of all of us over ten years. Like all concepts, it is very personal, and it is no wonder that participants spent some time debating the meaning of the term (as was done at Varna and Maryland) without satisfying anyone. Whatever one's personal concept, it seems to have been agreed that integrated science is universal science and that in 1978 we were more likely than in 1968 to find children who can evaluate evidence, rather than accepting the teacher's authority. At the same time, a child's view of science and technology will depend on his social setting. Lions lurk in the path of integrated science teaching, and the teacher should be on the alert for a conflict of values, for example on the question of astronomy *vis-à-vis* astrology. This is another example of the heavy responsibility of science teachers mentioned by Terlouw.

In his paper Pitre expressed a concern that I shall summarize as $dc/dt \gg ds/dt$, where c is curriculum change and s is social change. Whether or not one advocates evolution instead of revolution, there is no doubt that certain curricular elements needed in some countries would be quite out of place, even incomprehensible, in other countries. The practice of adopting curricula from other countries is long dead; and adaptation has slowly been giving way to the creation of new curricula tailor-made for the local situation as we science educators come to understand what integrated science can do for the children who are our responsibility.

Another matter which received a lot of attention at the conference was the so-called dichotomy between developed and developing countries. I am not at all sure of how to classify a developing

country in the context of the growth of integrated science education. It is true that in terms of *quantity* of human and material resources, there is a dichotomy. It is also true that the first science curriculum innovators were the United States and the United Kingdom, but we ought not to extrapolate from these to developed countries as a species. We have only to contrast the amount of innovation in integrated science education in countries like Fiji, Jamaica and Swaziland with what is going on in science teaching in Argentina and France. The rest of the world has a lot to learn from the so-called developing countries; the conference provided one opportunity for this exchange, and perhaps the smaller countries have learnt that they should be walking tall.

So an international conference can help us as individuals to refine and enrich our concepts of integrated science education much more than can a national or even a regional conference. It also helps us at the very material level by giving us ideas and materials for our day-to-day work. In my job as a teacher educator I make regular use of materials collected at Maryland; and my function as Editor for this conference gave me advance sight of its papers, so that these also have already been used with my students. From these and other sources has been built up quite a collection of materials for science education in the West Indies, drawing on work in dozens of countries including Ghana, Lebanon, New Zealand, Peru, the Philippines, and the United States.

Some participants felt that the conference should have come up with a set of decisions. But how would that be useful or even possible? Stufflebeam has pointed out that, in decision making, there are three elements: the options, information about the options, and one's own values. All we were able to do at the conference was to identify the options and to share information about the options. The final step towards decision making must be taken by ourselves as individuals and by the educators with whom we work at home, in the societies in which we work, according to our own values.

Our profession, especially in integrated science, is refining and developing itself. We at the conference were standing on the shoulders of those who came before us. Since Varna, there have been Maryland, regional activities, four volumes in this New Trends series, numerous scholarly papers and much research, and at least 130 fully developed curricula. Nineteen seventy-nine is to be the Year of the Child. I believe that our integrated science teaching will in the future be much more suited to our own children growing up in the 1980s than the dead knowledge that characterized our so-called science teaching in the days before Varna.

But I believe we should waste no time. Terlouw has shown that science and technology are powerful and dangerous forces in society, and that science teachers shape the future. There is so much more that children have to learn if they are even to survive in the next decade. It is my belief that significant progress is unlikely to occur without a commitment and a tremendous amount of work from science teachers' associations working nationally, regionally and internationally. I am sure there is no other way.



Appendix I. Guidelines for the introduction of integrated science

Thomas Gadsden, Paul Becht and
George Dawson

Editorial Note: The Nijmegen Conference explicitly looked both backward and forward, and Rafael Ferreyra's chapter suggested the need, among others, for guides which would help a country to use the experience of others to introduce integrated science.' The authors of this paper have experience of small and large scale curriculum development, and offer some very practical advice for those to whom an integrated science curriculum development project would be a new venture.

Figure 1 may be useful in understanding how the various components of the process of integrated

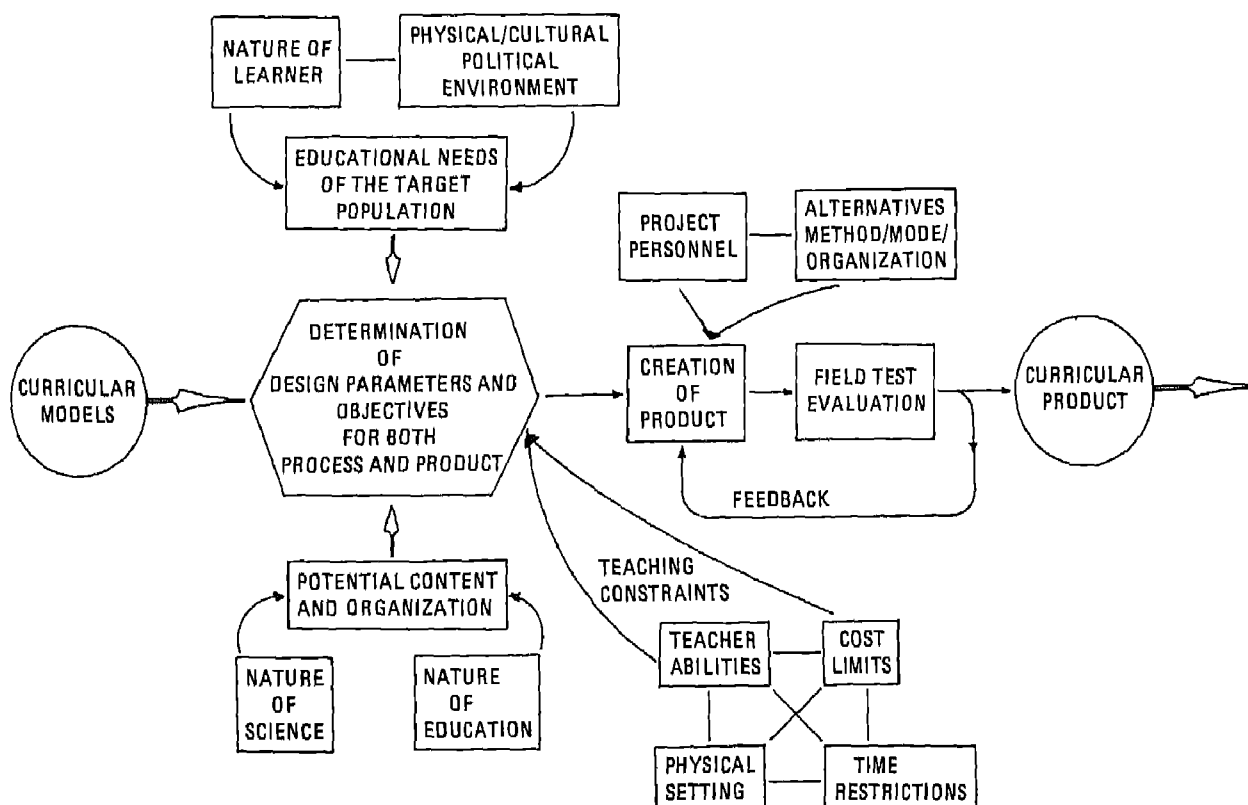


Figure 1. Process of integrated science curriculum development

science curriculum development mesh together to yield a curricular product, and in summarizing the elements of curriculum development.

INITIATING A PROJECT

All projects begin with a need (we shall later give some examples of needs that have led to science projects) which may be formalized *needs assessments* or may be more informal. The data from such an assessment are usually examined by one person who then becomes the catalytic agent to formulate and conduct the project. Judging from experience round the world, an educator at any level may initiate a project that will revolutionize educational practice, so that if you have good ideas and submit them in a proper and timely way, they may very well become a reality. You should be prepared, though, for the fact that it may be several years before the project is financially supported and at the materials production stage. There will be many obstacles on the way.

SELECTION OF STAFF

After you have convinced key people of the worth of your project, the biggest task is selecting staff. Integrated science curriculum development faces a far bigger problem than development in, say, biology, since the staff's background must be so much broader.

IDENTIFICATION OF CHARACTERISTICS OF TARGET POPULATION

'For whom is the curriculum?' The answer cannot just be 'O Level students' or 'twelfth grade students', but should describe the students as specifically as possible. Are they from a rural area? Is the target population to be all the children within a country? Or only the very bright? Or the very poor? Must there be accommodation for ability level? Before we can even prepare a proposal, we must obtain information about, and pay attention to, age, mental abilities in general, academic background, home environments, career orientations, language differences, cultural characteristics and religious beliefs. The characteristics of the students to whom you will address your project will determine the type of writers you select.

IDENTIFICATION OF NEEDS

Unfortunately needs are identified more in relation to outside influences than to careful consideration of long-range priorities and social planning. The release of funds is usually stimulated by pressures which have nothing to do with education in its true sense, but we must not ignore the opportunities that can arise. The astute curriculum developer must try to anticipate the pressures to which his educational system will be subjected in the years ahead, and take advantage of them in his plans to reach the students.

Within the member states of the Organization of Petroleum Producing Countries (OPEC), major shifts in science curricula are taking place due to the need for nationals trained in scientific and technological skills. Some OPEC educators foresaw this and had their plans ready for the appropriate decision-makers when the time was right.

In the United States, those educators who were ready have seized the opportunity to exploit three major thrusts.

Energy conservation. With the 1975 fuel shortage, science educators began planning a curriculum development that was to teach energy conservation. Bureaucracies work slowly, but results are now being seen as governmental agencies are releasing funds for a topic that only a few years ago was unsellable.

Bilingual/bicultural education. Several years ago, ISCS became interested in the plight of students in America whose native languages were not English. The prevailing approach was to teach them English and then teach them science. To many educators, this seemed terribly unfair. First, many 'teachable moments' would be lost during those months or years required to give students a sufficient background in English. Second, the loss of the diverse languages would result, ultimately, in the loss of cultures. Third, the student was being penalized in the classroom, not from a lack of understanding of science but from the lack of English language facility required to express his understanding. The eight million Spanish-speaking people in the United States tend to be at the bottom of the socio-economic ladder due to inability to communicate in English. Although ISCS staff members had made initial plans for these people, it took several legal cases before the office of Bilingual Education was established. This has provided the funds to produce science materials in the Spanish language for use in the United States.

Equal opportunities for the handicapped. Recent decisions require schools and colleges to provide equal opportunities for the blind, the deaf, other physically handicapped, and the mentally handicapped. As a result, funds are now available to work in science education for these deserving people. Dr. Herbert Thier at the Lawrence Hall of Science, Berkeley, was ready and produced *Adapting Science Materials for the Blind (ASMB)*. [318].

If one is ready to begin, having a good plan, funds can usually be found when the climate is right.

SURVEY OF EXISTING MATERIALS

The next step is to document the materials and supplies that exist in the average school for which the curriculum is intended. If there is a deficiency, either the curriculum must be modified or schools must be supplied with more materials. At the University of the Philippines, Dr. Dolores Hernandez and her staff conducted surveys appropriate for adaptation and for which the supply of materials was feasible. The result was an adaptation of ISCS which uses locally available materials. [216, 421]

ESTABLISHMENT OF GOALS

What are the purposes of writing these unified science programmes? Are you interested in developing in students the ability to express themselves? To teach them the concepts of science? To make them lifelong learners? Is your purpose to better the society as a whole or, instead, the life of the individual? To help in establishing goals, some projects have brought together a cross-section of the people who could be affected (educators, representatives of government and business, parents, students and teachers) to form advisory committees.

In one successful model, the project initiator provides a general description of what he has in mind and asks the advisory board to write what they would like to see accomplished. These are all collected together, edited, typed and distributed to members for reactions. Although most members are not science educators, the benefits are good ideas for the project, broad based support, and clarification of the plan. A useful checklist for advisory boards has been provided by Grobman [390].

DESCRIPTION OF PHYSICAL SETTINGS

In what type of schools will the materials be used? Do the schools have adequate electrical, gas and water outlets? A survey will produce the answers to these questions. More than one well-conceived curriculum project has failed because the required facilities were not available in the schools. ISIS had no activity which demanded equipment, supplies and facilities not found in at least 70 percent of schools. Exceptions to this rule were reviewed on a case-by-case basis by

the project director, Ernest Burkman.

DETERMINATION OF THE BACKGROUND OF TEACHERS

How many years of schooling has a teacher had in the relevant disciplines? Is he trained in the type of learning style required in the programme? If some teachers may need special training, have you anticipated the needed teacher education materials and activities in your plans and funding proposals? Or will the student materials be easily usable by untrained teachers?

SELECTION OF THE CONTENT AND STYLE OF INSTRUCTION

In the light of information and understandings gained in the earlier stages of the project, decisions must now be made about the instructional format and scope of the planned programme. Will it be individualized so that students can work at their own pace and have some choice in the selection of materials? Or will it be based on group instruction with all students doing the same thing at the same time? How many months or years of schooling will the programme cover? Should it be a one-year or a multi-year sequence, or should it be a collection of brief modules that can be arranged into a course of almost any length? Which of these options is most acceptable to the target schools? What techniques will be used to integrate the content? Will the instructional experiences be inquiry-oriented, activity-oriented, field-oriented? How will decisions about content and instruction be made?

The SIEAS project of the Solomon Islands was developed with Unesco/Unicef support using the philosophy, 'Give a man a fish and you feed him for a day; teach him to fish and you feed him for life'. Maximum teacher and pupil involvement at the decision making level has led to an enthusiastic reception for the new curriculum, continuing teacher development, and modification of activities and units. [199]

ARTICULATION

Articulation with existing science programmes is important if the programme is to be accepted. The new programme should blend with the existing programmes which the student follows before and after his integrated science programme, even if these are non-science. Nuffield Combined Science is a good example of an acceptable science course for grades 7 and 8 designed to articulate with post grade 8 courses. [201]

HOW LONG DOES IT TAKE?

Figure 2 shows a Gantt time-line chart for an ISCS project. Note the amount of time allowed for the development of goals and objectives (many projects fail because of inadequate attention to carefully written ones).

WORKING WITH AUTHORS

In the early days, although the ISCS central staff had a fair idea of what they wanted to accomplish, they decided to employ authors to write specific performance objectives and then to write activities based on these objectives. This was a disaster because these authors had only a fuzzy idea of what they wanted to achieve with the students. So the ISCS leaders changed their tactics and in subsequent years employed science educators who were good at writing succinct, very specific, objectives. Then a scientist was employed to write a section of the instructional

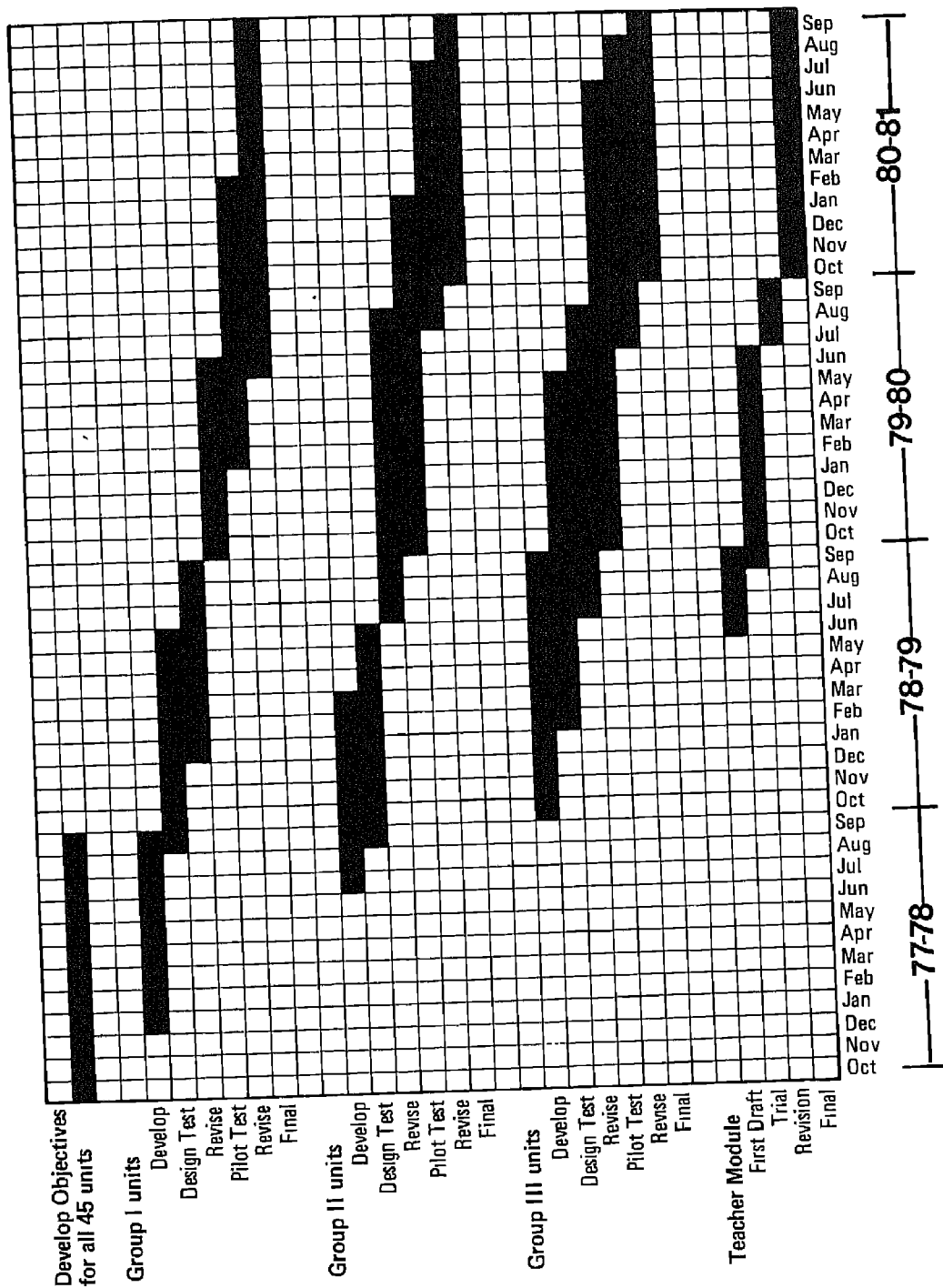


Figure 2 Gantt Chart Time-Line For ISCS Project

materials, given a highly specific set of objectives, the approximate number of pages he would have in the final edition, and an idea of the amount of art and photographic space he would have. These constraints did not limit creativity. At the very beginning the 'story line' was established, and this was maintained in the various drafts. Time invested at the beginning will usually pay off by reducing the total time to carry out the project.

Some projects have special training sessions for all new authors, including reviews of creative writing techniques, editorial shorthand, and instruction in the rationale, objectives and format of the programme so that rewriting and editing are reduced to a minimum.

Integrated science projects require major investments of time. Can you afford to devote that much time to a single programme? You must be able to answer 'yes' to the question; if the answer is 'no', stop before you waste what time you have.

QUALITY CONTROL

To ensure that the product goes out with as few errors as possible ISCS uses a sequence in which there is much checking and rechecking before the materials are released. This sequence is shown in Figure 3. There may of course be some variations according to the particular needs of other

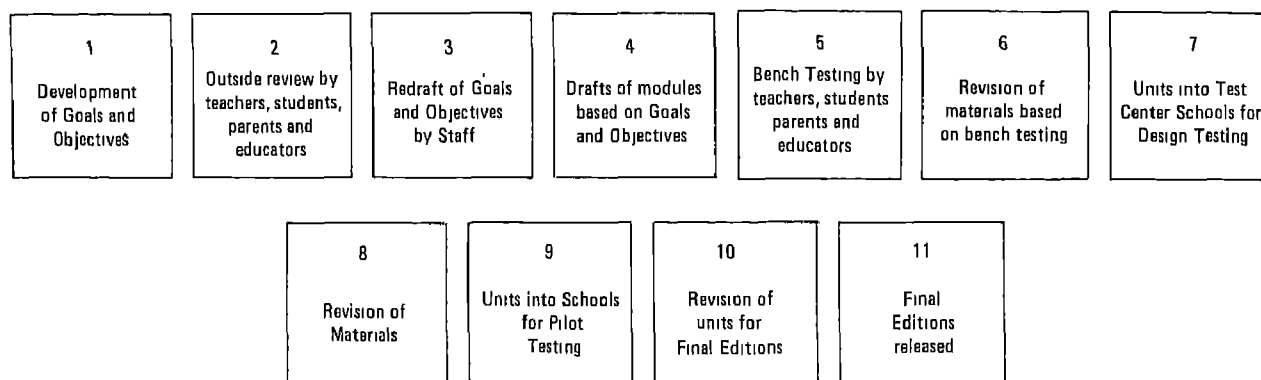


Figure 3: ISCS — quality control process

projects, but this basic flow is used by publishing houses and curriculum projects.

The ISCS project always insists that authors set up the activity as they have written it, no matter how often they may have done it or how sure they are that it will work.

DEVELOPMENT COSTS

Curriculum development in general is expensive. The ISCS project has been in existence since 1966 and has produced over 150 volumes of material. The total cost of the project has exceeded US\$4 million. Maybury estimates that the cost of training a development team and bringing them

together for several years to develop and trial-use a two-year course is about US\$275 000 (early 1970s) excluding any implementation costs. [216]

We have arrived at some estimates that may be helpful in preparing a budget. All times are in hours and all are averages.

AUTHOR:	To write a first draft of 30 pages:	10 - 15 days
ARTISTS:	Original· 3 or 4 pieces per 8 hours	
EDITING:	25 pages per day	
LAYOUT:	Paste-up· 20 pages per day	
TRANSLATING:	30 pages per day	
TYPING:	Rough draft: 25 pages per day	
FINAL TYPING:	Using composer typewriter. 15 pages per day	

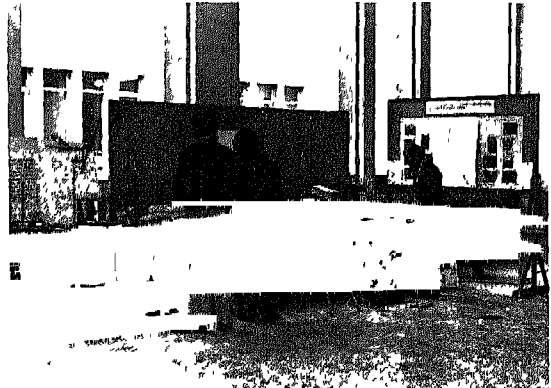
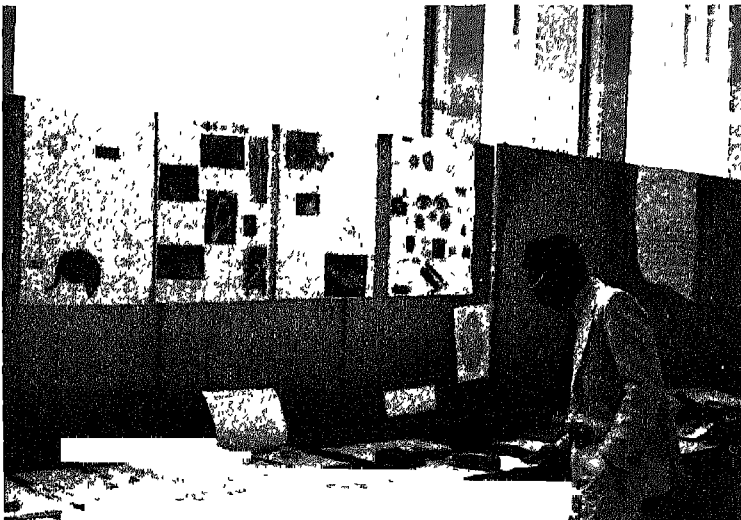
SUMMARY

A successful integrated science project requires more than careful attention to philosophy, goals, design, content and methodology. Equally important is careful attention to the process of curriculum development.

The first and probably most critical step is the selection of people who have ideas, a clear understanding of what is currently needed in science curricula and an insight into what will be needed in the future. As the project begins to move, careful and detailed planning becomes essential. The project staff must become deeply aware of the audience for whom they are working, their needs, their values and their interests. They must become familiar with the characteristics, positive and negative, of the environment that will help or hinder the programme. They must recognize their own special strengths and limitations. Realistic planning of time, money and effort are essential; little can be done to remedy unrealistic planning.

Even after careful planning and meticulous attention to details, the programme may not be completely successful. It is a very human temptation to blame the teachers; a more positive approach is to search for the conditions that decreased the effectiveness of the project, to identify ways to circumvent those conditions, and then to revise.

As we work toward better science education for our children, we must continuously build on the work of the past. From the successes, failures and experiences that we can share with one another will come the new ideas to set future directions in integrated science.



Curriculum units displayed in the poster session at the Nijmegen Conference

Appendix II. Bibliography on integrated science education

B. Benning, D. Lockard, V. Showalter
and B. Thomson

1. Abeles, T.P. Environmental education: a community/university approach. *Journal of College Science Teaching*, vol. 3, no. 1, October 1973, p. 50-3.

Describes an interdisciplinary environmental programme instigated at the University of Wisconsin. It was designed to utilize the community as a learning resource and to stimulate university/community interaction. The Kewaunee-River watershed project involved university and high school students, faculty and the community.

2. ACEID. Science curriculum with emphasis on the lower secondary school level. Paper EIA No. 41, *Inventory of Educational Innovations in Asia*. Bangkok, Asian Centre of Educational Innovation for Development.

3. Adams, I.K. Project for Science Education (lower secondary): progress report. *Journal of the Ghana Association of Science Teachers*, vol. 16, no. 1, June 1976, p. 34-7.

A description of Project for Science Integration (PSI) - its aims, methods and the stage reached in its development. Discusses the various trials through which the project materials have gone, some problems encountered and future directions the project may take.

4. Adey, P.S. Two tasks for the assessment of levels of cognitive development in Caribbean junior secondary schools. *Caribbean Journal of Education*, vol. 3, no. 2, April 1976, p. 112-38.

5. Ahlgren, A.; Walberg, H.J. Changing attitudes towards science among adolescents. *Nature* vol. 245, 1973, p. 187-90.

6. Akintola, J.M. The UPE Teacher Education Material Production Project. Report given before the Commonwealth Conference on Materials for Learning and Teaching, New Zealand, September 22 - October 3, 1975. Available from Nigeria Educational Research Council, Lagos, Nigeria.

Report of a project predicated on the fundamental belief that the most important and most cost-effective change agent is the well trained and motivated teacher and not the curriculum package. Pedagogically, the project is founded on the unity of knowledge, such

that in the handling of teaching or the monitoring of learning, attention is paid to both vertical and horizontal integration within and between subjects and subject fields.

7. Akizuki, Y. Trends and the Criticism of Integration in Science Education February 1975. Document available from the National Institute for Educational Research, Tokyo, Japan.

Activities, such as gathering knowledge from different fields of science in order to solve complex problems in the environment, may be establishing a new discipline, but cannot be considered as the integration of science. The important integrating science must be programmed carefully so that students understand the fundamental method of science, conditions where the object can be scientifically treated, how the science is established and developed and be able to view science as a whole. The best example of the integration can be seen in the development of dynamics from Galileo, Kepler to Newton.

8. Allen, G.E.; Collis, M. Integration in the primary school in theory and in practice. *School Science Review*, vol. 53, no. 185, June 1972, p. 689-95.

Supports the theory that learning for young children is naturally integrated. Describes the programme of a class of forty-two students for whom nearby redevelopment activities stimulated a variety of integrated learning experiences.

9. Alles, J.; Chiba, A. Environmental education at the pre-school and primary level. In: Aldrich, J. (ed.). *Trends in Environmental Education*, p. 81-99. Paris, Unesco, 1977.

Environmental education should not be viewed as yet another subject in schools. Environmental concerns should permeate all aspects of learning. Concerns regarding the environment, its imaginative utilization, its conservation and protection should be linked with all life tasks. With the incorporation of environmental concerns, the school learning situations may acquire a renewed quality, a wider character, and another overtone of relevance.

10. Andrew, M. Issue-centred science. *The Science Teacher*, February, 1970.

The author sees a major need for the development of some socially relevant, humanistic curriculum options. Various alternatives for integration are examined: chapters from different science courses, topics, or issues. An issue-centred, cross-disciplinary curriculum is seen to hold the most promise. Some ideas for possible issues are given.

11. Antoine, M.S.; Duret, A. (eds.). [Teaching and Environment] International Colloquy, Aix-en-Provence, October 16-21, 1972. [English translation of Environment]. Paris, La Documentation Française, 1973.

This international colloquy investigated the best means for environmentally educating today's youth. Emphasis is on incorporating environmental concerns into existing subject areas, not just the biological sciences.

12. Apea, E. A case study from Ghana. *Journal of the Ghana Association of Science Teachers*, vol. 16, no. 1, June 1976, p. 4-5.

Describes the role of the Ghana Association of Science Teachers in the development and implementation of PSI. The new curriculum being developed has broad aims at the primary, secondary and teacher training level. Considerable progress has been made at the secondary level where the PSI course has been developed for the first two years of secondary school. The course has been established around three major themes: the particulate nature of matter, transformation of energy, and life.

13. APEID-Unesco. *Science in Basic Functional Education: Philosophy, Approaches, Methods and Materials. Report of a Preparatory Working Group Meeting, Seoul, Republic of Korea, 7-12 July 1975.* Bangkok, Unesco Regional Office for Education in Asia, 1975. 49p.

Deals with issues and strategies of science education with a focus on development of new approaches and their implementation into instructional programmes as well as on the preparation of modules and instructional materials in other forms.
14. *Applied Science Graduate Studies in Israel.* Jerusalem: School of Applied Science and Technology, the Hebrew University, 1977. 50 p.
15. Australian Science Education Project. *Unit 401: A Guide to ASEP.* Melbourne, Victoria Government Printer, 1974. 115 p.; *A Guide to ASEP. Introduction to ASEP (Leader Edition, National Trial Print).* Toorak, ASEP, 1972.

Discusses the philosophy, objectives and evaluation of ASEP along with a complete outline of all the units.
16. Baez, A.V. *Innovation in Science Education World-wide,* Paris, Unesco, 1976. 249 p.

Describes recent efforts at improving science education and proposes strategies for change, a major recommendation being a systems approach to science education.
17. Ballada, M.Q. Improving mathematics skills through science concepts. *Studies in Science & Mathematics*, no. 1, September 1973, p. 28-33. Philippines.

Presents a unit designed for elementary school students using certain activities in science to develop some mathematics skills. The unit contains three topics, each providing from two to four lessons; and each lesson consists of two to four activities. The integrated activities are designed to make learning mathematics and science more interesting, meaningful and fun for children.
18. Barnes, D.G. An introductory science course for majors and non-majors. *Journal of College Science Teaching*, vol. 16, no. 1, September 1976.

This course, team taught and interdisciplinary, stresses broad applications and topics of current interest. Presentations and instructors are changed regularly. The laboratory experiences include computer programming, are varied regularly, and allow the student selection among several topics.
19. Battaglini, D. et. al. *Unified Science for Preservice Elementary Teachers.* Winona (Minn.) College of St. Teresa, 1975.

Provides specific details of three unified science courses for prospective elementary teachers. Each lesson ('mod') of each course is based on activities and materials selected from the various elementary science projects modified for use at adult levels.
20. _____, _____. Developing a humanistic, competency based curriculum for pre - service elementary science teachers. *Science Education*, vol. 59, no. 3, July - September, 1975, p. 357-71.

Describes the basic premises and course content of Unified Science I, II, and III which were designed to provide a more meaningful science background for prospective elementary teachers than that provided by conventional science courses.

21. Baum, J. Science and the humanities: bridging the crosscultural gap. *Science News*, vol. 107, no. 11, March 1975, p. 178-9.

States that there is reason for concern that interdisciplinary exchange in college between the arts, and science and technology, might accelerate the decline of competence within each discipline. Cites other reasons for apprehension related to interdisciplinary studies.
22. Bausor, J. Mathematics and science: uneasy truce or open hostilities? *Mathematics Teaching*, vol. 68, September, 1974.
23. Beament, J.W.L. The numerate ecologist. *Education in Science*, no. 66, January 1976, p. 23.

Comments on one of the points reviewed by a recent NERC Working Party on Quantitative Methods of Ecology that showed a need for better training in numerical methods for working and student ecologists. Suggests a course of geological mathematics.
24. Becht, P.A.; Gadsden, T. *The Aviology Concept Program*. Gainesville (Fla), P.K. Yonge Laboratory School, 1978. (Resource Monograph).

An overview and syllabus of a one-year integrated science programme built around the phenomenon of flight. Uses aviation as motivator to capture student's interest but also considers all forms of flight.
25. Bennett, D. Preparing the seedcorn. *Times Educational Supplement*, no. 3149, 10 October 1974, p. 44.

Discusses the Schools Council Integrated Science Project, Patterns, and the Project's materials.
26. Biggins, D.R. Science, society and the new apostasy. *The Australian Science Teachers' Journal*, May 1977, p. 9.
27. Binder, A. et al. Social ecology: an emerging multidiscipline. *Journal of Environmental Education*, February 1975.

Discusses the theoretical basis of a university social ecology programme expressed in biology, sociology, and psychology. It emphasizes man as a biological organism interacting in a cultural-physical environment. Since the programme is multidisciplinary and community-oriented, the organization is by problem area, such as man-environment interactions, not by discipline.
28. Bingham, C.D. The new Nuffield Combined Science Themes for the Middle Years. *Education in Science*, no. 69, September 1976, p. 15-8.

Presents recent modifications of the 1970 Nuffield Combined Science designed to meet the needs of children with a wide range of abilities at the middle school level. The materials in production are described along with a discussion on the use of the study and activity cards in various school situations.
29. _____; Elwell, M.J. Nuffield Foundation Combined Science in Middle Schools Continuation Project. *Education in Science*, January 1973, p. 29-32.

A report summarizing the findings of an enquiry into the use of Combined Science in

Middle schools. A total of forty-five schools was visited. Areas assessed included school buildings, staffing, daily pattern of working, storage, laboratory facilities, equipment, role of the science specialist, use of Combined Science with children under 11 years of age, and the relationship of Combined Science to the overall school curriculum.

30. Birch, C. Social responsibility in science. *The Australian Science Teachers Journal*, vol. 18, no. 1, March 1972, p. 19-25.

Esposes the thesis that science in the 1970s can be a responsibility pursued and taught only in the context of the needs of a world threatened by nuclear war, explosive population growth, depletion of essential resources, famine, pollution and meaninglessness.

31. ———. Social responsibility in science. *Search*, vol. 3, April 1972.

The author stresses that science in the 70s will be drastically different from science in the 60s. Exploding the myth of the neutrality of science, scientists will be forced to research scientifically areas that are urgently relevant to human needs. Scientists will be held responsible to interpret the significance of science to society, to assess its consequences and to influence its use. This calls for a different sort of training for the scientists of the future. School curricula will have to be relevant to the needs of man and his environment and must deal with such issues as population, pollution, conservation, resource utilization and the political and economic considerations related to scientific technology.

32. Bländsdorf, K. et al. (eds.). *The IPN - its Structure and Functions*, Kiel, Institute for Science Education, 1976. 82 p.

This booklet discusses the tasks, organization and general functions of the IPN along with information about projects initiated during the years 1973 - 1977 and discusses the projects that will be undertaken from 1977 to 1979.

33. Bloch, J.R. The analysis of integrated science curriculum materials. In: Cohen, D. (ed.). *New Trends in Integrated Science Teaching*, vol. IV, p. 37-52. Paris, Unesco, 1977.

Three functions of the analysis of curriculum materials are explored: training, research and evaluation. Emphasis is placed on the latter in relation to the goals, the setting and the role of the evaluator. Formalized schemes for analysis, created in the United States, the United Kingdom and the Federal Republic of Germany, are presented and reviewed in terms of the criteria for their construction and their use in analysing integrated science curricula. The concluding section considers the relationship of analysis schemes to integrated curricula in respect to both content and methodological considerations.

34. Blum, A. Decision points in planning an environmental education curriculum. *Environment and Society - Educational Priorities*. Proceedings of the European Conference on Environmental Education, London, 1977. Pergamon Press (in press).

A comparison between integrated environmental education curricula in different countries is used to show how decisions were made in determining the central topic. Various criteria for such decisions are discussed. Different frameworks can be used to introduce an integrated environmental curriculum unit into an educational system. The pros and cons of different approaches are discussed. Original curriculum development has become too costly and time consuming for most educational systems. A careful adaptation can be a good alternative solution. A Curriculum Adaptation Schedule, which can help to guide decision making in an adaptation, is described. The affective evaluation of an AES project unit is discussed.

35. Blumenthal, D.C. Science, politics and social change: course development in the area. *School Science and Mathematics*, vol. 73, no. 8, November 1973, p. 627-40.

Discusses the nature of science and technology and provides a number of examples to illustrate the impact that science and politics have had on each other. Advocates the need for the development of courses which integrate science, politics, and social change.

36. Booth, N. Interdisciplinary science. *Education and Culture*, vol. 27, Spring 1975, p. 22-30. (Council of Europe)

Discusses science education and how it must develop if it is to meet the needs of the individual and of society. Emphasizes appropriate objectives in relation to unity of the sciences.

37. Brown, S.A. Integrated science - a useful innovation? *Education in Science*, no. 59, 1974, p. 22-6.

38. ———. Affective Objectives in an Integrated Science Curriculum. Unpublished doctoral dissertation, University of Stirling, 1975.

Author developed an instrument to assess the achievement of five affective objectives of SISC. The instrument has five scales designed to measure: awareness of the inter-relationships between the different disciplines of science, awareness of the relationship of science to other areas of the school curriculum; awareness of the contributions of science to the social and economic life of the community; interest and enjoyment in science; and objectivity in observing and in assessing observations. The approach used in the development of this instrument can be used as a model for instrument development in evaluation studies. Its development and the results obtained with its use are described.

39. ———. *Attitude Goals in Secondary School Science*, Stirling, Stirling University, 1976. (Stirling Educational Monographs, 1.)

40. ———. A review of the meanings of, and arguments for, integrated science. *Studies in Science Education*, vol. 4, 1977, p. 31-62.

41. ———. Case study B. evaluation of attitude objectives. In: Cohen, D. (ed.). *New Trends in Integrated Science Teaching*, vol. IV, p. 158-65. Paris, Unesco, 1977.

This case study exemplifies evaluation of the attitudinal aspect of integrated science education. The approach is from two perspectives firstly, the purposes, meanings and feasibility of a group of attitude objectives are examined; secondly, the achievement of those objectives by pupils and the factors influencing the achievement are investigated.

42. ———. et al. *Innovations in Integrated Science in Scottish Secondary Schools*. Stirling, Stirling University, 1976.

43. Brown, W.R.; Wall, C.E. Look at the integration of science and math in the elementary school - 1976 *School Science & Mathematics*, vol. 76, no. 7, November 1976, p. 551-62.

44. Bryden, R.R.; Gifford, J.F. Interdisciplinary history of medicine as introduction to science. *Journal of College Science Teaching*, vol. 4, no. 5, May 1975, p. 301.

Discusses the relevance and validity of an interdisciplinary approach to teaching the

history of science. Describes a course in the history of medicine acceptable for college credit either as history or biology. References are cited.

45. Burden, I.J.; Turner, A.K.; Whittaker, M.J. Clowne Science Scheme - a method based course for the early years in secondary schools. *School Science Review*, vol. 57, no. 198, September 1975, p. 7-21.

A detailed discussion of the science programme developed at Clowne County Secondary School in Derbyshire. Includes the aims and objectives of the scheme, the teaching method and rôle of the teacher. An assessment of the programme is given along with some problems and observations. In this scheme, no attempt is made to impart a given body of knowledge to all the pupils during the first two years. In the first year, the overall theme is 'The Earth'. Second year students investigate 'The Senses', 'Time' and 'Rate of Change'. Structured content appears in the third year with a series of graded worksheets on a number of short topics taken from the separate sciences.

46. Caldwell, O. Preliminary report of the Committee on a Unified High School Science Course. *School Science and Mathematics*, February 1974.

Report of a committee of Central Association of Science and Mathematics teachers which explored '... better unification in aims and practices in science teaching, and better unification in the content of the science courses of the different years of the high school.' 'The need of unification of sciences is apparent to anyone who has studied the schools at first hand.' Describes objectives and purposes of science in schools. Provides an interesting historical perspective (note publication date).

47. *Canadian Environmental Concepts*. Project Canada West, Western Curriculum Project on Canada Studies, 1971. 42 p.

Describes a general high school interdisciplinary course on environmental studies. The course outline covers ecology, water pollution, air pollution, noise pollution, population, socio-economic implications and resource management. The period of study ranges from five to ten months. The course outlines, concepts and intended outcomes are described in some detail for the first two units - ecology and water pollution.

48. *Canadian Urban Dynamics: A Model for Student Involvement in the Urban Setting*. Project Canada West, Western Curriculum Project on Canada Studies, 1971, 31 p.

Progress report on a project to develop an interdisciplinary secondary school curriculum on the Canadian urban environment. The primary goal is to encourage constructive involvement in urban life and community decision-making, and to develop a personal and social competence that will engender a greater commitment to the city which is growing and changing.

49. Carson, S.M. *Environmental Studies: the Construction of an A-Level Syllabus*. London, National Foundation for Educational Research, 1971. 157 p.

Environmental studies for the upper secondary school. Interdisciplinary approach on the impact of human society on the environment.

50. —————; Ewer, D.W. Length, breadth and depth: reflections on the ecological approach. *Journal of Biological Education*, vol. 8, 1974, p. 145-52.

Stresses the need for an in-depth treatment of the socially-significant aspects of biology at the sixth form level. Suggests ecology as the central theme, not just in terms of the

immediate crisis, but integrated into the foundations of science, so that knowledge acquired by the student remains relevant as the fashion of alarm and despondency changes.

51. Cerovsky, J. Environmental Education - a Step Towards Solution of Environmental Problems by Changing People's Attitudes. ECE Symposium on Problems Relating to the Environment, New York, 1971. New York, United Nations.
52. ———; Environmental education: yes, but how? *Your Environment*, vol. 2, no. 1, Spring 1971.
53. ———; Environmental education as an integrating concept in science teaching. In: Richmond, P. (ed.). *New Trends in Integrated Science Teaching*, vol. II, p. 127-41, Paris, Unesco, 1973.

Develops the theme that environmental education serves as an ideal integrating concept for science teaching and for education generally. Three major stages can be distinguished; (a) teaching from the environment; (b) teaching about the environment, and (c) teaching for the environment. The emphasis in primary and secondary schools can correspond approximately to these stages. A curriculum based on the environment is integrated from the beginning and has advantages over co-ordinated or combined courses in which the disciplines are brought together.

54. Champaigne, A. An evolving unified science program at Powers. *Michigan State Teachers Bulletin*, Fall 1974.

Describes the gradual and planned changes in the unified science programme at Powers High School in Flint, Michigan. The present programme outline is presented as is its historical development and probable future directions.

55. Chapman, B. The integration of science or the disintegration of science education? *School Science Review*, vol. 58, no. 202, September 1976, p. 134-46.

Examines the move towards integration for science, noting that in the last decade the initial motivation for change seemed to be intrinsic to science and controlled by science educators. Recently, however, the motivation has tended to become extrinsic with both goals and subject matter dictated by a political concern outside the scientific realm. Major problems with integrated science are said to include: lack of definition of the term, lack of guidelines for planning curricula and inadequate standards for competence in this new field. Identifies the prime advocate of integrated science as 'administrative convenience' and discusses advantages to the school in handling problems, school imbalance of expertise within the science department, recruiting of new staff, laboratory requirements and uneven student elective choices.

56. Charles, D.J. Nuffield Combined Science - an evaluation. *School Science Review*, vol. 58, no. 202, September 1976, p. 129-34.

Report of a research study done at Exmouth School where Nuffield Combined Science has been used with the whole ability range of students in mixed ability groups. At the time of the study, eighteen science staff were involved in teaching year-groups of 420-450 pupils aged 11 to 13. Two separate questionnaires were administered to students and staff. Results of the survey indicated that Nuffield Combined Science is suitable and good for approximately the upper 75th percentile of the ability range. Below that it becomes increasingly difficult to adapt. The majority of staff expressed a reluctance to return to 'single sciences'.

57. Charters, W.W.; Jones, J.E. On the risk of appraising non-events in program evaluation. *Educational Researcher*, vol. 2, November 1973, p. 5-7.
58. Cheah, C.K. The lower secondary science curriculum development project. *Education in the Developing Countries of the Commonwealth - 1972-1975*. Singapore.

Through an integrated approach to the content of science, an attempt is made to weave together into a coherent whole, the various components of the scientific technological processes, concepts, terminology as they relate to the environmental and social aspects of life - population crowding, environmental pollution, high-rise and high-density living, etc. A theme approach is used.
59. ———; Lee, C.H. The Role of Social Biology and its Implications for School Science Teaching. Paper presented at the Asian Association for Biological Education in Asia Biennial Conference on Biology in Urban and Rural Areas of Asia, Singapore, October 1974.
60. Cohen, D. Evaluation in integrated science teaching - an introduction. In: Cohen, D. (ed.). *New Trends in Integrated Science Teaching*, vol. IV, p. 9-15. Paris, Unesco, 1977.

Discusses the meanings and interpretations of the term 'integration' and the need for new strategies of evaluation in integrated science teaching.
61. ———; (ed.). *New Trends in Integrated Science Teaching*. vol. IV: *Evaluation of Integrated Science Education*, Paris, Unesco, 1977, 199 p.

The publication seeks to present a thorough review and exemplification of current knowledge and practice in the field, and the authors have attempted a wide coverage of material and ideas. The first part of the book consists of chapters which review and analyse distinct aspects of the topic, as revealed by the literature throughout the world and the accounts of experimental projects and international, regional and national conferences. The second part comprises seven case studies of on-going evaluation projects in different parts of the world. These include accounts of the problems encountered when attempting to evaluate integrated science education in a concrete situation and some suggestions for tackling these problems.
62. ———; *Implementation of the Primary Science Scheme for the Territory*. Report to the Director, Northern Territory Division, Australian Department of Education, 1977. North Ryde (NSW), Macquarrie University. 26 p. (mimeo).
63. Collison, G.O. A new dimension in science curriculum development in Africa. *Journal of the Ghana Association of Science Teachers*, vol. 16, no. 1, June 1976, p. 9-18.

Recommends to African science educators the need to broaden the bases for curricular decisions and designs to include the cultural, linguistic and other factors which impede or enhance the performance of children in tasks requiring Western-type skills and abilities. There is a need for organized and systematic research by Africans aimed at identifying the possible cultural elements which will militate against or promote the development of scientific attitudes. As research findings are applied to modify existing programmes, the 'ultimate science programme' for Africa will evolve.
64. Comber, L.C.; Keeves, J.P. *Science Education in 19 Countries*. New York, Wiley, 1973.
65. Commonwealth Secretariat. *Low Cost Equipment*. Report of a Regional Seminar/Workshop, Bahamas, November 16-26, 1976. London, Commonwealth Secretariat, 1976. 98 p.

66. *Computers in the Undergraduate Science Curriculum (CUSC)*. (Document available from CUSC, Department of Physics and Astronomy, University College, London, WC1B 6BT)

Describes a project developing educational packages which utilize computers. The computer's main use is for simulation, which allows the science student to focus his attention on the way a physical, biological or chemical system reacts to a change of parameters. The technique also enables a student to consider and explore more realistic situations than the conventional 'soluble' examples normally used.

67. Cowan, D.J. Environmental topics in an undergraduate physics curriculum. *American Journal of Physics*, vol. 40, no. 12, December 1972, p. 1748-56.

Recognizing that the number of bachelor's degrees in physics awarded annually is declining, the author suggests that this trend may be reduced by increasing the versatility of the degree. One method is to apply physical principles to the following areas of environmental change: air pollution; energy conversion and resources; environmental radiation; noise; thermal pollution; transportation; and water pollution.

68. Cox, D. The Portland Project - program on the move. *School Science and Mathematics*, vol. 75, no. 1, January 1975, p. 87-92.

Describes the project from its inception in 1962 to its present state. Presents a topic outline and describes the variety of school settings and instructional methodologies that exist in the programme. Includes processes and directions by which the programme undergoes continuous evolution at the local level.

69. Creager, J.G. (ed.). Interdisciplinary environmental education. *The American Biology Teacher*, vol. 37, no. 2, February 1975 (Special issue).

70. Crofts, C.A. The inter-relation between mathematics and science teaching. *Education in Science*, no. 43, June 1971, p. 20-1.

Stressing the need for an integration of approach, the Education Committee of ASE makes a direct appeal to teachers of science and mathematics to submit examples of essential points of contact at all levels of the secondary age range.

71. Dale, D. Future studies and science literacy. *Pass-Age*, vol. 2, 1977.

This article analyses the concept of scientific literacy from the futurists viewpoint. Emphasis is placed on that particular dimension of scientific literacy which involves the interface between science and the rest of society. In general advises the science education community to seriously consider what twenty-first Century society would be like if the present purposes and objectives for teaching science were achieved completely.

72. D'Ambrosio, U. Sobre a integração do ensino de ciências e matemática. [On the integration of the teaching of science and mathematics]. *Ciência e Cultura*, vol. 26, no. 11, November 1974, p. 1003-10.

A position paper on the integration of mathematics to sciences in all levels of schooling, with special emphasis on the primary level. The paper presents the basic philosophy underlying the projects sponsored by OAS and the Ministry of Education of Brazil, for curricular development and the preparation of human resources, at the State University of Campinas, Brazil.

73. ———. Projectos integrados de matemática e ciências e uma opção para a formação de mestres para o ensino de ciências. [Integrated projects on mathematics and science and an option for the preparation of Masters in the Teaching of Science.] In: *Enseñanza Integrada de las Ciencias en America Latina 2*, p. 108-12. Montevideo, Unesco, 1975.

74. ———. Human Resources for Leadership in Science Education. Paper presented at the OAS Seminar on Science Education, Kingston, Jamaica, July 1976. Caracas, Centro 'El Macaro'. (n.d.)

Description of a graduate level, multinational programme, active since 1975, sponsored by OAS, for the training of leadership for science education with social relevance using local leadership.

75. ———. Ensino de ciências e desenvolvimento. [The teaching of science and development.] *Ciência e Cultura*, vol. 29, no. 2, February 1977, p. 143-50.

Special emphasis on the need for identifying and training local leadership to conduct curricular innovation and development with social relevance.

76. ———. Tradição e criatividade em ciências. [Tradition and creativity in science.] *Ciência e Cultura*, vol. 29, no. 5, May 1977, p. 532-6.

77. ———. *Desenvolvimento Nacional e Estratégias para Educação Científica* [National development and strategies for science education]. Campinas, IMECC-UNICAMP, 1977. 133+vi p.

A collection of essays dealing with mathematics and science education, in an integrated way, with aims directed towards development. The essays cover primary, secondary, tertiary and graduate levels, as well as research directions suitable for developing countries.

78. ———. *Science Education. Technology and Development: a Collection of Essays*. Campinas, IMECC-UNICAMP, 1978. 98+iv p.

A collection of essays dealing with science and mathematics directed towards developmental priorities. Both educational and research aspects are discussed, with strong emphasis on the role of computers and calculators in third world countries.

79. Dart, F.E. The cultural context of science teaching. *Search*, vol. 4, August 1973.

Describing his experiences with children of different backgrounds and cultures, the author stresses that we should consider this factor in curriculum planning. Different cultural groups have different value systems and different concept formations.

80. Dean, P.G. A view of computing, mathematics and science in British education. *School Science and Mathematics*, vol. 75, no. 1, January 1975, p. 21-9.

Outlines the use of computer programmes in modeling and simulation to provide a link between science and mathematics education.

81. Dence, J.B. Curricula in chemistry: presenting a balanced picture. *Journal of College Science Teaching*, vol. 3, no. 5, May 1974, p. 341-4.

Presents four examples which illustrate close relationships of chemistry to other

disciplines. Indicates that chemistry, composed of many strongly interacting parts, is a discipline which is donating to and borrowing from other disciplines.

82. ———. The Unified BCP Approach: some proposals for a non-major course as organized around the theme of the human system. *Science Education*, vol. 67, no. 2, April/June 1977, p. 167-77.

Proposes a one-year unified science course emphasizing the basic principles of biology, chemistry and physics in the organizing context of the human system.

83. DeVito, A.; Nordland, F. *Unifying, Simplifying, and Humanizing the Undergraduate Science Preparation of Prospective Elementary Teachers*. Lafayette (Ind.), Purdue University, 1975.

Presents arguments for revising the science content courses for prospective elementary teachers in terms of their needs, developmental levels, and the nature of the science materials from which they will be teaching which, in most cases, will be a form of unified or integrated science.

84. *The Do it Yourself Curriculum Guide*. Adelaide, Education Department of South Australia, 1974.

85. Dowdeswell, W.H.; Potter, I.C. An approach to ecology teaching at university level. *Journal of Biological Education*, vol. 8, 1974, p. 46-51.

An outline of an experimental ecology course at Bath University which includes: (1) an integration of zoological, botanical and micro-biological components; (2) simulation experiments in the laboratory, (3) an extensive use of slides, (4) the use of research papers; and (5) the utilization of personal research interests.

86. Dyasi, H. Three groups of skills essential for science teachers. *Cambridge Journal of Education*, vol. 17, no. 3, November 1977, p. 173-9.

Discusses the skills needed for pupil-focused science in primary schools, illustrated by examples from SEPA. Contribution to a special edition of the *Cambridge Journal* on 'Science and Scientific Thinking Across the Curriculum' (edited by Harlen). Easily read by teachers.

87. Edington, W.F.; Preville, E.J. A journey towards unity. *Engineering Education*, December 1974.

Traces the integration of engineering, humanities, and social sciences from the major objectives of 1955 to present curricula designed to produce the socio-engineer. Predicts future trends in curriculum development reflecting the growing relationship between technology and the values and condition of man.

88. *Education and the Environment*. Report of the multi-state conference, November 8-10, 1971, Annapolis (Md), Maryland State Department of Education, 1971. 27 p.

During the sessions participants from eight states were asked to respond to three major objectives by identifying: (a) the contribution of each subject area to a comprehensive programme of environmental education; (b) the contribution of interrelated approaches to environmental education and (c) new strategies of implementation as well as sources of funding for comprehensive environmental education programmes. Responses to these objectives constitute the bulk of the report.

89. Education Department of Victoria, Curriculum and Research Branch. *Beginning Science. Following On. Branching Out.*

Three booklets. The Branch also produces *Helix*, a regular newsletter about primary science for teachers, published twice yearly.

90. Eggleston, J.F. *An Examination of the Proposed Structure and Functions of the Educational Research and Development Centre in North West State (Nigeria).* Report of British Council Specialist Tour, February 1976. London, The British Council. 30 p.

91. Eichler, A. Environmental education at the secondary school level. In: Aldrich, J. (ed.). *Trends in Environmental Education*, p. 101-4. Paris, Unesco, 1977.

At the secondary school level, environmental study merits recognition as a permanent co-ordinator of the otherwise fragmented curriculum. It should not be considered as another 'subject' competing for a place in the existing school programme, but as a means of providing some unity to the educational process in the minds of the learners. Environmental education can be an effective tool for reorienting the whole concept of teaching and learning and for humanizing education. Suggested guidelines and objectives are given.

92. *Ekistics. a Guide for the Development of an Interdisciplinary Environmental Education Curriculum.* Sacramento, California State Department of Education, 1973. 76 p.

Offers structures and guidelines for developing a curriculum suited to local needs and meeting state requirements. The concepts developed for the study of conservation and environmental protection go beyond the more traditional nature study and appreciation to consider the areas of the social sciences and humanities. The definition and basis for ekistics are explored and ideas for developing the ekistics curriculum are expressed. Cognitive-affective frameworks and curriculum outlines for elementary, junior and senior high school levels are constructed for this purpose. A detailed example is given for the elementary school level. Strategies for teaching and learning at all levels are also discussed.

93. Elliot, L.G. *Gran de Integracao en Ciencias e Matematica nos Escolas Publicas de Nivel Primario na Cidade do Rio de Janeiro.* [Degree of integration in the curricula of science and mathematics in public schools on the primary level in the city of Rio de Janeiro.] Dissertation, Faculdade de Educacao da Universidade Federal do Rio de Janeiro, Brazil, 1976. 113+xi p.

A dissertation conducted towards the experimental analysis of theses presented by D'Ambrosio in the position paper published in *Ciência e Cultura*, vol. 26, no. 11, November 1974.

94. *L'environnement. Pedagogie*, no. 8, 1974, p. 643-704.

Suggests reawakening the pupils' interest in the life that surrounds them through introduction of ecology into the school curriculum. Theory leads to practical activities carried out in real-life situations - a natural multidisciplinary education.

95. Esler, W.K.; Merritt, K. Teaching and reading through science experience stories. *School Science and Mathematics*, vol. 76, no. 3, March 1976, p. 203-6.

96. Eulefeld, G. Environmental Education - How to Organize Interdisciplinary Small Group Work with Out-of-School Activities in the Existing School System in the Federal Republic

of Germany. (Available from the Institute for Science Education, Universität Kiel, Kiel, Federal Republic of Germany).

Provides a brief overview of the school system in the Federal Republic of Germany, and of the situation of the introduction of environmental education in the syllabus. Using the topic of water pollution as an example, the current form of multidisciplinary environmental education is illustrated and the need for an interdisciplinary approach to this field is founded. Organizational difficulties and possibilities in the school system are mentioned and the interdisciplinary IPN-project 'Problems of Water Pollution' is described. Two excerpts from the guiding programmes for the pupils are introduced as examples of how to instruct pupils in independent outdoor activities.

97. ———, An ecological approach to restructuring school biology. *Journal of Biological Education*, vol. 10, no. 4, August 1976, p. 196-202.

Suggests the use of a human-centred ecological structuring principle based on the physical existence of man as an individual and as a species. Recommends the reciprocal relationship between man and his environment as the focal point. Suggested as an approach for pupils aged 10 to 15 at the secondary school level.

98. European Communities Biologists Association. *Biology Curricula at Universities*. Report of Workshop, Amsterdam, 1976. Amsterdam, ECBA, 1976.

99. Evans, P. Technology in the primary school. *School Science Review*, vol. 58, no. 205, June 1977, p. 635-57.

100. *Experimental Course of Integrated Science for Elementary School Teachers*. (Available from PRONAMEC, P.O. Box 3845, Lima, Peru.)

Describes a course intended only for elementary school teachers involving the following subject matters: modern mathematics, developmental psychology, laboratory work in physics, chemistry, and biology, all as a basis for individual and team project work. Along with the subject matter, teachers took methodology in integrated science teaching both as discussion classes and as practical work in the lab. Plans are to extend this programme up to the 9th grade of basic education training.

101. *Expert Panel on Educational Activities Under the Man and the Biosphere Programme: Final Report*. Paris, Unesco, 1972. 54 p.

Outlines activities in environmental education to be promoted under the MAB programme. Refers to post-graduate courses, seminars, and interdisciplinary research, as well as to publications on the biosphere. Also refers to relations with other international organizations.

102. Fagan, E. Interdisciplinary bonding. *English Journal*, vol. 65, October 1976, p. 31-4.

103. Faulkner, H.; Mansell, S. Coming to an understanding - Nuffield science and home economics. *Times Educational Supplement*, no. 3180, 14 May 1976, p. 51.

104. Fensham, P.J. The nature and knowledge of the sciences. *Search*, vol. 8, 1977, p. 26-32.

This paper discusses the ways the content of science courses are determined and how much the separate disciplines dominate school science teaching.

105. Ferrell, T.L. Interdisciplinary program at a small college. *American Journal of Physics*, October 1975.
- Describes a time-tested programme of interdisciplinary service courses at a small college. Presents advantages as well as drawbacks.
106. Fertitta, N.V. A K-12 unified science approach. *School Science and Mathematics*, vol. 75, no. 1, January 1975, p. 65-9.
- The science curriculum in Anne Arundel County, Maryland, specifies a scheme for major unifying concepts in science and a scheme for scientific literacy as the basic structure of the programme.
107. Fieblinger, G. Das verhältnis von naturwissenschaft und gesellschaftlichen arbeitsprozess - qualifikationsanforderungen an den naturwissenschaftlich/technischen unterricht. In: Ewers, M. (ed.). *Naturwissenschaftliche Didaktik Zwischen Kritik und Konstruktion*, p. 105-32. Weinheim, Beltz-Verlag, 1975.
- Describes an attempt to determine the meaning of natural science in relation to production (technical development etc.) with some general conclusions concerning science teaching.
108. Firouz, E. Opening Address to the Regional Seminar on Training of Environmental Guards and Officers. Tehran, Iran Department of the Environment, November 1975.
- Environmental problems in Iran have great cultural and geographic importance. The Department of the Environment has the task of preventing spoilation of the environment, as well as the task of educating the public in this matter. This has led to the training of environmental guards and officers through a two-year programme of physical and intellectual growth. Courses in ecology and wildlife management, as well as first aid and self-defence, are included.
109. *Five to Nine: Urbanization and the Social Studies Curriculum for the First Four Years (K-3) of Canadian Schools*. Project Canada West, Western Curriculum Project on Canada Studies, 1971. 60 p.
- The Powell River Project was designed by a team of primary school teachers to develop a curriculum with the urban environment as a major focus. Activities and experiences were selected which lead the child to learn his role in society, to understand the relationship between groups, the interdependence of people and institutions, and how they are affected by urbanized environments.
110. Fort, T.; Poscover, B. Report on Society-Environment-Science. *American Biology Teacher*, vol. 36, no. 2, February 1974, p. 105-6, 116.
- Describes a programme called 'Society-Environment-Science' which has been offered for three years at Lansdowne Senior High School (Baltimore, Md). It is a one semester, interdisciplinary course that is team-taught by a social-studies teacher and a science teacher.
111. Fowler, J.M. Science and society - scientific and technological aspects of current problems of society. In: Lewis, J.L. (ed.). *New Trends in Physics Teaching*, vol. III, p. 224-33. Paris, Unesco, 1976.
112. Fraser, B.J. Are ASEP pupils achieving the aims of science education? *Australian Science Teachers Journal*, November 1970, p. 25-34.

113. ———; Are ASEP's stated aims worth achieving? *Australian Science Teachers Journal*, November 1970, p. 130-2.

114. Frey, K. Integrated Science Education in the Federal Republic of Germany. Presented at the Symposium on an Interdisciplinary Approach Towards the Teaching of Science Subjects at the Secondary Level, Exeter, 8-14 September 1974. 37 p. (Available from the Council of Europe, Strasbourg, France.)

This report gives a survey of the place of integrated science education in the curriculum of the general school system, a simple analytical representation of the approaches on which integrated science education is based in the Federal Republic of Germany, and works out some of the trends of the integrated curriculum within the whole science and technical school education system. It discusses three major problems of integrated science instruction. The first problem involves the lack of detail with which methods of teaching integrated science have been described. The second problem involves the qualifications necessary for the teacher to be competent in the classroom. The third problem is a lack of recognized and acknowledged structure in the new field.

115. ———; The Concept 'Integrated Science Curriculum'. Background paper for the Symposium on an Interdisciplinary Approach Towards the Teaching of Science Subjects at the Secondary Level. Exeter, 8-14 September 1974. 9 p. (Available from IPN, University of Kiel, Kiel, Federal Republic of Germany).

A short introduction to the historical development and the problem background of the concept 'Integrated Science Curriculum'. Proposes a new definition: 'An integrated science curriculum is a learning system which includes information from or associated with the science disciplines; this information is, on the basis of a comprehensive curricular approach, restructured and functional for educational purposes.'

116. ———; Drei probleme des integrierten naturwissenschaftlichen unterrichts. *Der Mathematische und Naturwissenschaftliche Unterricht*, 1975, p. 326-9.

117. ———; Ein modell der lehrerbildung: das lehrerinformations und lernsystem (L-I-L System). [A model for teacher education]. In: Aregger, K.; Flechsig, K.H.; Lattmann, U. (eds.) *Lehrerbildung für die Schulreform*. Bern, UTB Haupt., 1975.

118. ———; Methodology and Main Areas of Research on Science Education. a Framework. Paper presented at Contact Workshop, Kiel, 27-29 October 1976. (Available from IPN).

Describes the science educators' sphere of activity. Discusses and responds to what the author considers fundamental questions of science education. Presents rules for and areas of research to add new dimensions to science teaching.

119. ———; Blänsdorf, K. (eds.). *Integriertes Curriculum Naturwissenschaft der Sekundarstufe I. Projekte und Innovationsstrategien*. Bericht über das 5. IPN-Symposium. [Integrated science curriculum of the secondary level I. Report of the 5th IPN-Symposium.] Weinheim, Beltz-Verlag, 1974. 633 p.

120. Gadsden, T. et al. Cutting boundaries with correlated science. *School Science and Mathematics*, vol. 75, no. 1, January 1975, p. 80-6.

Article deals with the philosophy, instructional techniques and outline of a three-year high school integrated science course 'Correlated Science' developed at P.K. Yonge Laboratory School, University of Florida, Gainesville, Florida. Explores problems encountered in developing and implementing the programmes likely to be encountered in

similar projects.

121. Gamage, C.S. An example of co-operation between industry and schools. *School Science Review*, vol. 55, no. 193, June 1974, p. 674-82.

A brief description of ESSO's educational programme. Some of the phases described include the Industrial Fund and Senior Loan Service which helped schools with laboratories and equipment, the Junior Loan Service which provided an eight term syllabus for introducing science into preparatory schools along with all the materials likely to be required by participating teachers and their pupils, and training films for science teachers unfamiliar with the newly developed curricula.

122. Gardner, M. A myriad of patterns on the international scene. *School Science and Mathematics*, vol. 75, no. 1, January 1975, p. 69-79.

Describes integrated science activity by Unesco and in the Philippines, Singapore, Thailand, Malaysia, Japan, Australia, the United Kingdom, Israel, and the Caribbean.

123. Gennaro, E.D.; Glenn, A.D. Science and social studies: an interdisciplinary approach to values and value decisions. *Science Education*, vol. 59, no. 1, January - March 1975.

Identifies common areas of interest for the sciences and social studies. Explains effective clarification strategies and methods of focusing on value conflicts. Two such methods, the analytical model and moral reasoning model, are explained and examples of instructional materials provided for each.

124. Glenn, A.D.; Gennaro, E.D. Interdisciplinary approach for exploring value and value questions for social studies and science teachers. *High School Journal*, vol. 58, February 1975, p. 208-23.

125. Gordon, G.E. et al. Chemistry of Man's environment: a course for non-science majors. *Journal of Chemical Education*, vol. 51, no. 10, October 1974, p. 668-71.

Describes an environmental chemistry course in terms of its objectives, philosophy, topics, principles, laboratory experiments, texts, supplementary material, and student response.

126. Goudswaard, J.; Teitelbaum, M. Learning environments for environmental education. In: Aldrich, J. (ed.). *Trends in Environmental Education*, p. 49-62. Paris, Unesco, 1977.

In a broad discussion of learning environments, the authors suggest that multi-discipline approaches and team teaching can help teachers develop their ability to teach environmental education. Environmental themes can be studied through the disciplines that are currently taught in most schools; the educational potential of an environmental experience will be vastly enhanced by activities which emphasize the complex inter-relationships among all the elements that support the world.

127. Greeley, W. et al. Final Report - Unified Studies Program. Boston, Boston State College, 1975. (Unified studies report 1-10).

Summarizes the experiences of the staff of the Unified Studies Program at Boston State College from September, 1973 through August, 1975. Some of the more significant experiences involved: a) introduction to 'trans-disciplinary' methodology, b) introduction to the nature of team teaching, c) confrontation of faculty with unified educational theories.

128. Gresswell, B. The changing function of science education. *School Science Review*, vo. 54, no. 188, March 1973, p. 584-7.

Suggests that the function of science education needs to be broadened to provide a curriculum which includes a study of the social and political aspects of science. Pupils need to see a career in science and technology as socially relevant and a positive combination to the development of society.

129. Griffin, N.C. *Interrelated Explorations in Science for Middle School: a Report of Field Study*. Gainesville (Fla), P.K. Yonge Laboratory School, University of Florida, 1976. 75 p. (Research Monograph 11.)

This monograph deals with the philosophy, objectives, evaluation and course content of the three year, unified science programme 'Interrelated Explorations in Science' developed for 12-14 year olds at P.K. Yonge Laboratory School, University of Florida, Gainesville, Florida.

130. Griffiths, K.G., Smart, R.S. An experiment in interdisciplinary science teaching - Preliminary Year Science, University of Papua New Guinea. *Science Education*, vol. 59, January - March 1975, p. 27-38.

Outlines the problems and attempted solutions leading to the structure of a first year interdisciplinary science course. Presents the history and development of the course, staffing procedure, and structure of the course.

131. Griffiths, R. Making musical instruments as a springboard to science and mathematics integration. *Science and Children*, vol. 13, no. 3, November 1975, p. 7-10.

132. Gruber, G.; Koch, B. Die integration von historisch-gesellschaftlichen lernzielen in den naturwissenschaftlich-technischen sachunterricht. *Die Deutsche Schule*, vol. 69, no. 3, 1977, p. 176-86.

Shows the interdependence of natural science, technology and production and explains why a natural science curriculum should be based on this insight. The authors give the main principles for selecting, weighting and structuring the components of an integrated science curriculum according to their concept. Some teaching materials are illustrated.

133. Haas, J.D. For lack of a loom problems in integrating knowledge. *School Science and Mathematics*, vol. 75, no. 1, January 1975, p. 4-14.

Indicates that human problems of the future will demand integrative ideas and solutions. This integration requires a unifying theme to overcome the educational specialization that has been created by a technological society.

134. Haggis, S.M. Trends in the teaching of integrated science world wide. In: May, J. (ed.). *Report of a Conference Organized by the Arab League Educational, Cultural and Scientific Organization, Cairo, May 1976*. London, Chelsea College Centre for Science Education, 1976. (mimeo) p. 28-34.

This paper presents an overview of the trends in teaching integrated science worldwide that indicate a trend toward teaching about the environment.

135. Hall, S.K. Environmental science for the non-science major. *Journal of College Science Teaching*, vol. 3, no. 3, February 1974, p. 211-2.

Describes the structure and content of a multidisciplinary environmental science course for non-science majors offered at Southern Illinois University.

136. Hall, W.C. 'Patterns' - The Schools Council Integrated Science Project. *School Science and Mathematics*, vol. 75, no. 1, January 1975, p. 115-20.

Describes a course developed in the United Kingdom that uses a patterns approach to science teaching. Outlines eleven novel features of the course and describes a method of integration that offers complete instructional flexibility.

137. Hallas, G., Hughes, W.J. An alternative syllabus in A-level chemistry based on the place of chemistry in industry and its effects upon society. *School Science Review*, vol. 56, no. 194, September 1974, p. 164-9.

Discusses the Core-Plus-Options structure of the syllabus.

138. ———; ———. The JMB Applied Chemistry syllabus - the place of case studies and industrial processes. *School Science Review*, vol. 56, no. 195, December 1974, p. 391-8.

Discusses two topics included in the core programme of the JMB alternative syllabus in A-level Chemistry. These are the social and economic aspects of chemical technology, involving the use of six case studies and industrial processes.

139. Hallett, L.R.; Kalman, C.S. Constellation course: interaction between the sciences and the arts. *American Journal of Physics*, vol. 43, no. 7, July 1975, p. 606-9.

Discusses a two-semester college course focusing on the idea that developments in the sciences and the arts together reveal a constant process of mutual influence and cross-fertilization. The course develops this thesis using examples from physics, art, literature, and philosophy from Greek times to the present day.

140. Harder, P.J. Activity cards bridge science and social studies. *Science and Children*, vol. 12, no. 7, April 1975, p. 8-10.

141. Harlen, W. *Science 5-13: a Formative Evaluation*. London, Macmillan, 1975. 128 p.

Describes the development and working of the project and gives an account of procedures used for evaluation in the final phase and of the results obtained.

142. ———. The role of evaluation in adapting learning experiences in integrated science to differences between pupils. In: Cohen, D. (ed.). *New Trends in Integrated Science Teaching*, vol. IV, p. 111-30. Paris, Unesco, 1977.

Begins with a discussion of the importance of adapting learning experiences to differences between pupils. What this means in practice is described in terms of a model which represents the adaptation of the learning environment as a succession of adjustments, a process in which evaluation plays a central part. A series of dimensions is defined describing variation in features of the learning environment which are thought most relevant to catering for differences between individuals. Various programmes, at primary, middle and secondary level, are outlined and described by profiles using these dimensions. Finally, some of the ways which teachers can use to gather information about the individual characteristics of pupils which affect learning are discussed and illustrated with examples from the programmes developed in different countries.

143. ———. Match and Mismatch. (Available from University of Reading, Reading RG1 5AQ, United Kingdom.)

A concise description of the Schools Council PLS project. The aim of this project is to provide help for teachers who are in the process of deciding which of various possible activities and approaches is likely to interest and help a particular child. The thrust has been to prepare local leaders who will then run courses for teachers of 5 to 13 year olds in their locality. Three general themes reflect the main aspects of the matching problem: making and recording observations about children, making decisions about the learning environment and children's development and learning.

144. ———. A stronger teacher role in curriculum development? *Journal of Curriculum Studies*, vol. 9, no. 1, May 1977, p. 21-9.

Examines teacher participation in curriculum development in terms of teachers' rôles - research and in development in the United Kingdom context.

145. ———. Progress in Learning Science Project. Paper given at IIEP Seminar on Teaching-Learning Strategies and Educational Planning. Paris, IIEP, 1977.

Describes a teacher preparation project which provides training and guidance for teachers to use existing resources effectively within a strategy for matching activities and approaches to the characteristics of individual learners. To facilitate comparison of this strategy with others, it is described in terms of relative positions along a series of nine dimensions representing the most important features which can vary from one strategy to another. The implications of the Progress in Learning Science strategy as they relate to curriculum development, teachers' training, and organization at school and classroom levels are discussed. A brief history of the project is provided and a report given on progress made to date.

146. ———. Does content matter in primary science? *School Science Review*, vol. 60, no. 209, June 1978, p. 614-25.

147. ———; Chen, D. Introducing science into Israel's elementary schools: the work of the MATAL Project. *Educational Development International*, vol. 2, no. 1, January 1974, p. 39-43.

Describes the background, origin and general scheme of a project which aims to retrain teachers of elementary age children in new methods and acquaint them with new materials. The new direction is toward active child involvement with guided learning and away from the teacher delivering knowledge. Materials have been developed and a comprehensive programme prepared for reaching teachers in all parts of the country.

148. Harrison, G.B., Dutton, P.E. The challenge of including technological activities in school science. *Education in Science*, no. 71, January 1977, p. 15-7.

Presents three principal characteristics of technology that enable it to be structured into the teaching of any science syllabus. These are: (1) that awareness of technology is of social concern, (2) technology is at heart a creative design process similar to the scientific method, and (3) that it relies on available resources, one of the principal resources being the knowledge of science. The authors suggest that the inclusion of technological activities brings extra opportunities for motivation of pupils as well as showing them that science is a useful and usable subject.

149. Hausman, H.J. *Choosing a Science Program for the Elementary School*. Washington, (DC),

Council for Basic Education, 1976. 45 p. (Occasional Papers 24.)

This monograph deals with the kinds of elementary school science programmes available today in the United States and how teachers and schools might go about choosing among them. The use of the integrated science programme S-APA is discussed.

150. Häussler, P. Der aufbau von integrierten naturwissenschaftlichen curricula: vergleichend darstellung von projekten. In: Frey, K., and Blänsdorf, K. (eds.). *Integriertes Curriculum Naturwissenschaft der Sekundarstufe I Projekte und Innovationsstrategien*, p. 75-112. Weinheim, Beltz-Verlag, 1974.

Describes the major integrated science projects recently developed in the United States the United Kingdom and the Federal Republic of Germany. The author tries to classify these according to their basic ideas.

151. Hecht, K.; Blänsdorf, K. (eds.). *Implementation of Curricula in Science Education*. Report of an international seminar on The Implementation of Curricula in Science Education with Special Regard to the Teaching of Physics organized by the Federal Republic of Germany's National Commission for Unesco and the Institute for Science Education, Kiel, 16-18 March 1972. Pullach/Munich: Verlag Dokumentation, 1973. 202 p.

152. Hegarty, H.M.; Aldrich, P.R. New ideas on student motivation: English and science. *Agriculture Education Magazine*, vol. 45, March 1973, p. 203.

153. Hepburn, M.A.; Simpson, R.D. Can the curriculum save us? *Social Studies*, vol. 66, no. 2 March/April 1975, p. 65-9.

An interdisciplinary approach to environmental education, incorporating both the sciences and social sciences, is presented.

154. Herman, G. Science. rhythm and rocks. *Teacher*, vol. 92, November 1974, p. 52.

This article shows how the rondo, a musical form, can help integrate movement, language, art and music into science.

155. Hinton, K.; May, J. *The Place of Science in Environmental Education*. Hatfield (Herts), Association for Science Education, 1974. 17 p.

A very good statement on the status of integrated science in the United Kingdom, some environmental science education projects, and on how science can serve as a base for environmental education; illustrative concepts provided.

156. Holton, G. *Thematic Origins of Scientific Thought*. Cambridge (Mass), Harvard University Press, 1973.

Makes a case for the persistence and importance of a relatively small number of themes in guiding scientific thinking throughout history. One of the examples given and referred to often is the theme of force. Another is that of equilibrium or balance.

157. ———. Sociobiology: the new synthesis? *Newsletter on Science, Technology and Human Values*, October 1977.

Describes some of the features of sociobiology and the author's impressions of the potential scientific and social value of combining biological science and behavioural

science, each of which is a synthesis of several sciences.

158. Humphreys, L. *Techniques of Unified Education*. Boston (Mass), Boston State College, 1974. (Unified Studies Report 1-9.)

Describes techniques that may be used to unify studies in all fields at all levels of learning. Among the techniques are: linkage exercises, whole-problem-solving exercise, analogy and metaphor exercise, and model exercise.

159. Hurd, P.D. Science, technology, and society: new goals for interdisciplinary science teaching. *The Science Teacher*, vol. 42, no. 2, February 1975, p. 27-30.

Puts forth and develops arguments for new perspectives in teaching science and suggests an interdisciplinary approach to curriculum which focuses on human values and social dilemmas. This view includes other subject areas along with science.

160. Hyder, M. Art and science. *School and Community*, vol. 62, May 1976, p. 37.

161. Individualized Science Instructional System. *Managing ISIS*. Tallahassee (Fla) The Florida State University Educational Research Institute, 1976. 35 p. (Revised trial draft).

This booklet describes the uses of the instructional minicourses and tells how to organize the classroom so that individualized instruction can take place.

162. *Integrated Science Curriculum Innovation Project*. (Available from the Curriculum Development Unit, University of Dublin, Dublin, Ireland)

Presents background on the development of the Integrated Science Curriculum Innovation Project (ISCIP), a three-year science programme leading to Intermediate or Group Certificate examination standard. The Curriculum Development Unit, responsible for the Integrated Science Project and an Integrated Humanities Project, is comprised of representatives of the City of Dublin V.E.C., Trinity College Dublin and the Department of Education. Both programmes are geared to the needs of students and based on their own community.

163. Integrated science (O-level) - questions and answers. *Science Education Centre Newsletter*, vol. 8, no. 3, March 1977, p. 12-3.

Synopsis of the main issues raised at the September 1976 meeting of the Association of Science Teachers of Jamaica. Purpose of meeting was to air constructive critical comments on the draft syllabus for integrated science (CXC).

164. Integrated Science Programme. (Available from Vikram A. Sarabhai Community Science Centre, Narrangpura, Ahmedabad 380009, India).

Presents the rationale for undertaking the development of a three-year curriculum in integrated science at the secondary school level. This report includes the topics developed, the instructional approach to learning as well as the mechanics involved in the development and trial of materials. The programme was initiated in 1972.

165. Integrated science and SCISP. *Science Education Centre Newsletter*, vol. 5, February 1974, p. 14-9; *Education in Science*, November 1973.

Reviews a study concerning what Northern Ireland pupils think of SCISP. One hundred and eighty-six pupils in six schools completed the course and were candidates for the GCE examination in Integrated Science in 1973. A questionnaire of thirty-nine items designed to assess pupils' attitudes to the project was used. Results of the survey indicated that pupils accepted SCISP as a very reasonable course, found it enjoyable and were enthusiastic about some aspects.

166. *Integration, Co-ordination or Separation of Sciences at University Level*. Report of Seminar, Paris, May 1974. International Council of Scientific Unions Committee on the Teaching of Science. 6 p., appendices.
167. *Introducing Match and Mismatch*. London, Schools Council, 1977, 28 p. (Progress in Learning Science Information Paper 7.)

A brief profile of a project begun in 1973 designed to help teachers of 5 to 13 year olds match children's learning experiences to development in the various skills, concepts and attitudes involved. The materials of the project, the specific guidelines and suggestions made are illustrated with reference to science, although the approach can be applied in many subject areas. Materials produced by this teacher-training project include two books for teachers, a leader's guide and a set of audio-visual aids to use during in-service study.

168. Ito, N. *et al.* Basic science in upper secondary school education in Japan. *Science Education*. Part I in vol. 59, no. 4, October/December 1975, p. 475-80, Part II in vol. 60, no. 4, October/December 1976, p. 441-52.

Detailed description of philosophy and course structure of a basic science course for high schools in Japan. Can be used as total course in several arrangements or as partial programmes.

169. Japanese National Commission for Unesco. *Regional Meeting for Science Education Improvement in Asia: Final Report*. Japan, 1973.

A report of a seminar on needs and problems of science education at primary, secondary and out-of-school levels.

170. Jeffrey, A.W. Case study A: Evaluation of the Scottish Integrated Science Syllabus. In: Cohen, D. (ed.). *New Trends in Integrated Science Teaching*, vol. IV, p. 152-8. Paris, Unesco, 1977.

This case study outlines the development and evaluation of a course of study in integrated science for the first two years of secondary education in Scotland. It describes how the principle of 'rolling' development is carried out, outlines the various evaluative procedures which were used and gives some of the results of these procedures and the conclusions which the authors of the syllabus drew from them. The final section indicates the nature of the continuing investigation and some of the more recent developments in consequence.

171. Jenkins, W.E. Are school chemistry courses too professional? *School Science Review*, vol. 56, no. 196, March 1975, p. 617-9.

Suggests that many current syllabuses have resulted from pressures brought by the community of practising chemists rather than as a response to the wider but more diffuse needs of the community at large. Notes that despite attempts at relevance, most courses are still within a rigidly defined academic framework. There is need to assert, in

curriculum terms, that chemistry has something to contribute to general education.

172. Jensen, R.G., Jensen, K.C. *Syracuse-Yugoslav Project on Environmental Policy and Planning*. Syracuse (N.Y.), Syracuse University Graduate School, 1973.

The Syracuse-Yugoslav Project will develop an interdisciplinary analysis of environmental problems in Yugoslavia, a decentralized socialist society undergoing rapid urbanization and economic development. The project is based at the Urban Institute in Ljubljana. Project activities in both research and education involve joint work by American and Yugoslav experts in environmental education. Project objectives focus on: (a) socio-economic problems of environmental policy and planning with attention to areas where the experience of one country can provide ideas and alternatives for solving the environmental problems of another; (b) means of increasing the exchange of information on environmental problems between Yugoslavia and the United States; and (c) the production of materials describing and analysing environmental problems in Yugoslavia that can be used to enrich environmental curricula in the United States.

173. Jevons, F.R., Turner, H.D. *What Kinds of Graduates Do We Need?* Oxford, Oxford University Press, 1972. (Science and Engineering Policy Series.)

Discusses the ways science graduates are employed and contribute in society, and hence how science education should occur.

174. Karplus, R. *Reasoning Patterns*. (Workshop on General Science Teaching and the Development of Reasoning.) Berkeley, University of California, 1977. 140 p.

175. Kattmann, U.; Isensee, W. (eds.). *Strukturen des Biologie-unterrichts*. Cologne, Aulis-Verlag, 1975.

A survey of new trends and projects in biology with special emphasis on integrated science.

176. ———; Schaefer, G. New approaches to restructuring school biology. *Journal of Biological Education*, vol. 10, no. 3, June 1976, p. 139-47.

Describes two approaches to restructuring school biology. A human-centered approach would cover those specifically human activities within the living world as a whole including the psychological characteristics of the individual and of the human groups. A cybernetic approach would use four concepts for the structuring of biology teaching: system, model, control and regulation and information.

177. Kay, S. Curriculum innovations and traditional culture: a case history of Kenya. *Journal of Comparative Education*, vol. 11, no. 3, October 1975, p. 183.

178. Kelly, P.J. *Curriculum Diffusion Research Project*. Report to SSRC. London, Chelsea College Centre for Science Education, April 1975. 71 p. (mimeo).

179. Kerr, J.F. Evaluating student progress in integrated science - public examinations. In: Cohen, D. (ed.). *New Trends in Integrated Science Teaching*, vol. IV. p. 95-111. Paris, Unesco, 1977.

Is concerned with ways of improving public examinations, not only to discriminate between individuals but also to contribute to the mastery of those skills and concepts which the teacher and the curriculum developer desire. The effects of public examin-

ations on teaching and learning integrated science are analysed. Techniques of examining are reviewed, problems identified and the way ahead considered.

180. Kershaw, I.; Scott, P.J. Science for pupils of low educational attainment. *School Science Review*, vol. 56, no. 196, March 1975, p. 449-63.

Outlines one school's efforts to provide a science course for pupils who are less academically motivated. The strategy was one of adopting a modular structure with much of the work integrated with that of non-science departments.

181. Kesteven, G.L.; Maddever, R.S. Ecosystem approach to science teaching. *Education News*, vol. 11, February 1967, p. 16-8.

Discussion of the Geelong Grammar School Project which organizes science teaching by way of systematic and continued examination of natural systems. The general aims of the project are. (1) to give students opportunities for employing various scientific techniques in a real research project; (2) to enable students to gain a view of the relations between various fields of scientific enquiry and an understanding of the interdependence of disciplines; (3) to give students a view of an integrated project bearing upon a clearly identifiable ecosystem; (4) to give individual students opportunities for pursuing particular studies within a general project and with the assistance of specialists; (5) to give students the opportunity of meeting specialist scientists; (6) to assist teachers to use the lagoon and materials from it as objects for class exercises in science, geography and other disciplines, (7) to give the masters contacts with the scientific community; and (8) to give an opportunity of demonstrating to students the relations between social and natural sciences.

182. Kirman, J.M.; Nay, M.A. Joint planning for integrating social studies and science. *Social Education*, vol. 29, February 1975, p. 77-80.

A model for the joint planning and integration of science and social studies is presented. Curriculum comparisons, topic selection, topic definition and integration, and operational strategies form the basis of the model. Suggestions for implementing the model and evaluation processes are also included.

183. Knamiller, G.W. Happenings as an alternative. *School Science and Mathematics*, vol. 74, no. 3, March 1974, p. 183-8.

Suggests that the elementary school curriculum need not be fragmented into discipline areas and describes a class activity that cuts across the traditional boundaries and is interdisciplinary in nature.

184. Krasilchik, M. Evaluation of the Integrated Science Project in Brazil. In: Cohen, D. (ed.). *New Trends in Integrated Science Teaching*, vol. IV, p. 166-72. Paris, Unesco, 1977.

Describes the designing of the evaluation component of the integrated science project developed in Brazil. Discusses decisions, points and problems faced by a project director when planning and conducting evaluation study. Expected and unexpected results are outlined as well as possible alternatives to solve problems in similar situations. Evaluation of this project is not yet completed and thus this report is preliminary rather than final in nature.

185. Khun, D.J. The Contemporary Issues Module: its use in the science methods class. *American Biology Teacher*, vol. 35, no. 2, February 1973, p. 77-80.

Describes pre-service education for science teachers by engaging students in modules stressing contemporary issues. Basic features of the modules include providing individualized instruction and stressing the interdisciplinary aspects of pure, applied, and social science.

186. Kurtz, R., James, R.K. Implementation of an integrated program of science: a Process Approach and Nuffield Mathematics. *School Science and Mathematics*, vol. 75, no. 3, March 1975, p. 258-66.

187. Labianca, D.A. Science for the nonscience major through interdisciplinary study: the interrelation of science and art. *Science Education*, vol. 59, no. 2, April/June 1975, p. 187-90.

Describes a way of teaching science designed to stimulate interest among non-science majors to help make science a more meaningful subject to them. Attention is focused on the study of a particular type of air pollution and on the use of the discipline of art to examine the effects of this pollution.

188. ———; Reeves, W.J. Teaching synergistic drug interaction to nonscience majors: an interdisciplinary approach. *Science Education*, vol. 59, no. 4, October/December 1975, p. 461-5.

189. LaHart, D.E., Tillis, C.R. (eds.). *Strategies for Multidisciplinary Environmental Education*. Tallahassee (Fla), State Department of Education, Division of Elementary and Secondary Education, 1974. 78 p.

A collection of papers, each of which develops an intellectual framework for teaching a particular discipline within an environmental context. The subjects included are political science, health education, language or communication arts, art, science, mathematics and social studies.

190. Lambert, E.N. New directions in science education in the 70s. *Journal of Education in Science for Trinidad & Tobago*, vol. 2, no. 1, October 1974, p. 26-38.

In terms of the needs for science education in developing and underdeveloped countries, the author suggests the main features of science education in the 70s should be: (1) a movement towards integrated science; (2) the highlighting of science for social awareness and social responsibility; and (3) the development of a relevant curriculum.

191. Lawrence, S.G. Education in a threatened planet - the part that science teaching could play. *School Science Review*, vol. 53, no. 183, December 1971, p. 269-73.

A plea for a programme in human ecology which should be more than just another subject - it should be a philosophy, an outlook on life and should inform the teaching of all subjects, especially the sciences. Discusses how A-Level, O-Level, CSE and non-examination courses in science might be modified. Desires that the science teacher, at whatever level he teaches, should become more of a generalist and less a specialist.

192. Layton, D. *Science for the People*. London, George Allen & Unwin, 1973. 226 p. (Reviewed by W.H. Dowdeswell in *School Science Review*, vol. 56, September 1974, p. 214.

Vivid and penetrating analysis of attempts to introduce the teaching of the science of 'common things' into elementary schools of the mid-nineteenth century. Compares the situation as it existed then with circumstances facing us today.

193. ———; A wider spectrum of aims. *Trends in Education*, vol. 25, January, 1972, p. 11-12. (HMSO).
194. Lerner, L.S., Gosselin, E.A. Physics and history as a bridge across the 'two-cultures' gap. *American Journal of Physics*, vol. 43, no. 1, January 1975, p. 13-9.

Describes a course for college seniors, science majors and non-majors, designed to trace the development of modern science as part of western culture. Reports three years of experience. An outline of the course and a reading list are included. Refers to specific sciences but, also, to commonalities among them.
195. Lewis, J.L. Science in society. In: *GIREP Seminar on the Teaching of Physics in Schools: 2*. Copenhagen, Gyldendalske Boghandel, p. 393-404.
196. Liao, T.; Piel, E.J. Let's get relevant. *The Physics Teacher*, vol. 8, 1970, p. 74-9.
197. Linderman, L. *An Analysis of the Unified Science Modular Unit Approach to Science Instruction in Terms of Piaget, Bruner, Ausubel and Gagne*. Columbus, Ohio, FUSE Center for Unified Science Education, 1976.

Presents specific aspects of the guidelines advocated by FUSE for the structure of unified science instructional units in perspective to various contemporary theories of learning. Takes a typical unit with the recommended structure and suggests modifications of the basis of each of these theories.
198. Lockard, J.D. (ed.). *New Unesco Source Book for Science Teaching*. Paris, Unesco, 1974. 270 p.
199. ———. *Science and Mathematics Curricular Developments Internationally 1956-1974*. Ninth Report of the International Clearinghouse on Science and Mathematics Curricular Developments. College Park, University of Maryland, AAAS 1974. 395 p.
200. ———. Regional and international co-operation for the improvement of biology education. In: Unesco. *New Trends in Biology Teaching*, vol. IV, p. 225-32. Paris, Unesco, 1977.

The published paper presented at the Unesco International Conference on Biology Teaching held at Uppsala, Sweden in 1975. Summarizes various co-operative efforts around the world related to improving biology teaching.
201. ———. (ed.). *Twenty Years of Science and Mathematics Curriculum Development*. Tenth Report of the International Clearinghouse on Science and Mathematics Curricular Developments. College Park, The International Clearinghouse, University of Maryland, 1977. 515 p.

Provides detailed information on the major science and mathematics curriculum projects from around the world that are now in developmental or active dissemination stages including the integrated projects. Includes, also, a 20-year cumulative directory to all projects, 1956-1976.
202. Lomon, E.L. et al. Real problem solving in USMES: interdisciplinary education and much more. *School Science and Mathematics*, vol. 75, no. 1, January 1975, p. 53-64.

Based on experiences with USMES. States that real problem-solving must become an

effective and integral part of education at all levels. Describes the relationship of real problem solving to the USMES class, interdisciplinary education, and the total school programme.

203. The Lower Secondary Science Curriculum Development Project. *Scientas - Bulletin of the Science Teachers Association of Singapore*, vol. 10, October 1975.

204. Luce, T.S.; Volksdorf, N.R. *Evaluation of a University Course in the Environment: Final Report*. Tulsa (Okla), Tulsa University, 1972. 24 p.

The primary purpose of this study was to evaluate the effectiveness of the university-level multi-disciplinary course on the environment. This course attempts to bring about heightened awareness of environmental events as reported in the mass media. A second related study sought to determine whether particular values characteristically associated with the various disciplines could be modified by such a course experience. Two assessment procedures were administered to sixty-one students both before and after a multi-disciplinary university course, Science, Technology and the Environment. Data indicate that there was a decrease in awareness of environmental events at the end of the course. The subjects were found to show little change in their value judgements as a result of the course.

205. Lutterodt, S.A. The diffusion of PSI. What sort of reception will it get? *Journal of the Ghana Association of Science Teachers*, vol. 16, no. 1, June 1976, p. 37-42.

Report of a study carried out during the course of the annual GAST conference in August 1974. The study was designed to find out to what extent the attitudes and opinions of teachers coincided with those which had informed the development of the programme of the Project for Science Integration and how far teachers accepted its philosophy and approach. On the whole the teachers were well disposed towards the new curriculum. Four problem areas identified indicate that (1) teachers should be informed about the main characteristics of integrated science, (2) teachers should be given a realistic appraisal of the problems in introducing PSI; (3) concrete guidelines should be provided to help teachers; and (4) particular attention should be paid to explaining why PSI has rejected formal teaching techniques such as note taking and why vocabulary, definitions and all the complicated machinery of normal scientific initiation have been given such a reduced place.

206. McCabe, R.H. *Man and Environment for Secondary Schools: a Curriculum in Environmental Studies for High Schools*. Miami (Fla), National Association for Environmental Education, 1972. 96 p.

This curriculum guide, developed by a workshop in environmental studies for secondary schools at Las Vegas, contains twenty programmes for integrated environmental studies in the secondary school. Each programme includes an overview, a list of concepts and a list of student objectives. In addition, an appendix has suggestions for initiating and implementing the programme in the regular school curriculum. References and possible resources are given.

207. McCarley, O. *Science Education News - Unified Science Education*. Washington (DC), American Association for the Advancement of Science, 1969.

Contains statements regarding the promise of unified science education and descriptions of five unique secondary school unified science programmes. Describes the course content and rationale within each of the programmes.

208. McCurdy, P.P. Is there an integrator in the house? *Chemical and Engineering News*, April 1973.

Discusses reasons for current disenchantment with science and appeals for concentration on cross-fertilized models in contrast with the differentiation among scientific disciplines.

209. McInnis, N. What makes environment educational? In: McInnis, N.; Albrecht, D. (eds.). *What Makes Education Environmental?* p. 23-34. Washington (DC), Environmental Educators, 1975.

210. ———; Albrecht, D. (eds.). *What Makes Education Environmental?* Washington (DC); Environmental Educators, Inc.; and Louisville (Ky), Data Courier, Inc., 1975.

An excellent collection of papers written specifically for this publication. They represent a complete picture of environmental education in the United States, covering the basis for environmental education, instruction, environmental perception and communication, dissemination of environmental education, and environmental education needs.

211. Macedo, L.J. de. *Guia Curricular para Ensino Integrado de Ciências 1º grau*. [Curricular guide for integrated teaching of sciences. 1st degree] Goiânia. Colégio de Aplicação da Faculdade de Educação, Universidade Federal de Goiás, 1978.

212. Mannino, S. A course of co-ordinated sciences: the structure of matter. *Science Education*, vol. 60, no. 4, October/December 1976, p. 559-65.

Describes generally a course of co-ordinated science prepared by the Group of Science Education Research at the University of Palermo, Italy. Presents the general outlines of the first part of the course, the Structure of Matter, and describes in detail the physical sciences branch of the course.

213. Markward, D.C. *A Comparison of Natural Science Scores on the ACT Attained by Students at Moline High School Having Unified Science Courses with Those Having General Science Courses*. Macomb, Western Illinois University, 1976.

Reports a study involving 324 high school seniors with either general science or unified science course experience. Findings indicate that the unified science students scored considerably higher on the ACT Natural Science Test, even after adjustment for IQ differences.

214. Martin, G.C.; and Wheeler, K. (eds.). *Insights into Environmental Education*. Oliver & Boyd, 1975. 199 p.

Nineteen exponents of environmental education throughout the world present case studies describing interdisciplinary insights which could be starting points for curriculum development. Further reading is suggested at the end of each article. Designed to stimulate discussion among students and teachers and provides questions and useful addresses.

215. Matthews, P.S.C. Has science education a future? *School Science Review*, vol. 57, no. 198, September 1975, p. 157-62.

Questions whether some of the present trends in science education will actually result in the failure to teach science; and thereby lead to the replacement of science by

non-science subjects in the curriculum. Current emphasis is education through science rather than science education. Will this result in sufficient, adequately-trained scientists for the future?

216. Maybury, R.H. *Technical Assistance and Innovation in Science Education*. New York, John Wiley, 1975. 210 p. (Special issue of *Science Education*.)

A detailed report to the Ford Foundation on the history and status of five science curriculum development projects. Includes extensive conclusions and recommendations regarding funding of similar large scale ventures. Many projects reported began with discipline focus and evolved to integrated.

217. Mayer, V.J.; Richmond, J.M. Evaluation instruments for integrated science teaching. In: Cohen, D. (ed.). *New Trends in Integrated Science Teaching*, vol. IV, p. 65-78. Paris, Unesco, 1977.

Reviews briefly data-collecting procedures useful in evaluation studies of integrated science teaching. It focuses especially upon objective respondent-completed instruments identified in a world-wide survey of science educators. The instruments are categorized and representative examples of each category are discussed. Recommendations are suggested for instrument use and development.

218. Meador, C.L. Fundamental paradigms: toward unified approaches to science in education. *Engineering Education*, May 1973.

Describes the respective problem-solving procedures, namely, the rule-formula application-oriented and the strategy-oriented in engineering and science as pre-conceived notions of each profession. Concludes that the fundamental paradigm is a unified model fitting many apparently unrelated bodies of knowledge.

219. Mendes, P. Estudo Descrit de um Modelo Curricular de Curso Inestruturado. [Descriptive study of a curricular model for instructional course.] Dissertation, IMECC-UNICAMP, Sao Paulo, Brazil, 1978. 85 p.

An analysis of a graduate level, multinational programme, sponsored by OAS which trains local leadership to conduct curricular innovation and development with social relevance.

220. Meyer, R. Developments in the training and retraining of school biology teachers. In: Unesco. *New Trends in Biology Teaching*, vol.IV, p. 153-96. Paris, Unesco, 1977.

221. Mikelskis, H.; Lauterbach, R. Energy Through Nuclear Power Plants - a Model for Interdisciplinary Education. (Available from IPN, University of Kiel, Kiel, Federal Republic of Germany.)

In this instructional unit of the IPN Physics Curriculum, a new type of interdisciplinary physics education is designed and evaluated. It may be characterized: (1) as a student's curriculum (the unit is written for both teachers and students in order to initiate and support interactive decision-making in the teaching-learning process); (2) as an integrated Curriculum (the main aspects of the public discussion about nuclear power supply, i.e. physical, technical, ecological, political, economic and historical are taken into consideration); and (3) as an open curriculum (the unit contains selected materials from the public controversy and offers some alternatives of using it on the basis of trial experiences in different schools. The unit's organization permits for every instructional planning to start with the knowledge, interests and preferences of

the students.

222. Moore, R.W. et al. Integrating science. *Science and Children*, vol. 11, no. 7, April 1974, p. 10-12.

223. Motz, R.W. Science-social studies camping course: river communities, past and present. *American Biology Teacher*, vol. 37, no. 4, April 1975, p. 241-2.

224. Mylechreest, M. Whither rural studies? *School Science Review*, vol. 57, no. 199, December 1975, p. 276-84.

Considers the changing position of rural studies in the secondary school curriculum and some of the implications in relation to science teaching. Examines rural studies within the environmental studies context envisioning co-operation of teachers of rural studies, biology, physical science and geography.

225. Nash, M. Mapping, collecting, classifying, identifying. *Times Educational Supplement*, no. 3149, 10 October 1974, p. 31.

226. Nay, M.A. What hath humankind wrought? A plea for interdisciplinary education. *Alberta Science Education*, vol. 14, no. 1, January 1976, p. 22-35.

Presents a case for interdisciplinary education based upon education's role in society as an agent for social change. Identifies a spectrum of existing approaches to interdisciplinary programming ranging from situations where one subject is pre-requisite knowledge for the learning of another to programmes where there is total integration of content from several disciplines. Recommending the latter approach, the author suggests two methods which make possible a combination of diverse disciplines: a problem-centred approach to the human and social condition of society and a life-experience approach focusing upon the type of immediate personal and social concerns common to all youth.

227. Neulieb, M.H.; Neulieb, R. Hemodynamics: biophysics for AP Biology. *American Biology Teacher*, vol. 37, no. 6, September 1975, p. 346-9.

Discusses the physics of fluids flowing through vessels in the context of blood moving in the circulatory system. The method of presentation used is judged suitable for students in an advanced high school science course emphasizing individualized instruction in an interdisciplinary field.

228. Novick, S. Evaluation studies: the use of formative evaluation procedures for improvement of a socially-oriented course in chemistry. *Studies in Educational Evaluation*, vol. 2, no. 1, Spring 1976, p. 1-7.

Describes the interactions with teachers which yielded information for the revision of a socially-oriented chemistry course designed for non-science majors. The procedure used yielded both general and detailed information concerning course content, societal relevance, motivation and interest, laboratory and demonstration exercises, other classroom or individual exercises and teaching problems.

229. Oakley, J.S. Reflections on integration of mathematics and science. *School Science and Mathematics*, vol. 74, no. 4, April 1974, p. 293-6.

Describes a sixth grade programme in which science and mathematics are integrated and

emphasis is given to providing students with individual attention.

230. Odhiambo, T.R. The planning and teaching of science according to national needs. *Impact of Science on Society*, vol. 23, April/June 1973, p. 95. Paris, Unesco.

The article examines the needs for science education in African countries.

231. Ohashi, H. Evaluation of integrated science teaching in Japan. In: Cohen, D. (ed.). *New Trends in Integrated Science Teaching*, vol. IV, p. 186-94. Paris, Unesco, 1977.

In this case study, student achievement and performance are evaluated in order to obtain useful data for the improvement of the national 'Course of Study', curricula and instructional methods. The ensuing discussion delineates the effects of the mode of evaluation on student attitudes toward learning science and indicates the necessity for a more comprehensive kind of evaluation.

232. Olgers, A.J., Riesenkamp, J. Docentenopleiding: doelstellingen (1), (2), (3) and (4). [Research on objectives for teacher education.] *Resonans*, vol. 9, no. 1, September 1976, p. 2-5; vol. 9, no. 5, January 1977, p. 117-22; vol. 9, no. 10, June 1977, p. 218-21; vol. 10, no. 5, January 1978, p. 138-42.

233. Ontario Department of Education. *Man, Science and Technology. (A guideline)*. 1972.

234. O'Reilly, S.A. Some ideas for energy projects in schools and colleges. *School Science Review*, vol. 56, no. 195, December 1974, p. 388-91.

Suggests that projects on energy tend to cross discipline boundaries and can be meaningful to student groups of ranging ability and interests. Appropriate projects are suggested.

235. Ost, D.H. Changing curriculum patterns in science, mathematics and social studies. *School Science and Mathematics*, vol. 75, no. 1, January 1975, p. 48-52.

Describes briefly six various types of unified or integrated approaches to science curriculum development each of which has promise in terms of improved science education in the future.

236. Palma-Vittorelli, M.B. A course of co-ordinated science. *Science Education*, vol. 60, no. 4, October/December 1976, p. 559-65.

A report on the structure and content of the co-ordinated science programme in Italy. Reports a unique approach to integrating with two separate branches interwoven and using the same concepts. Describes a course developed in Palermo which is intended for students, aged 14, in a compulsory secondary school. Introductory in nature, the course emphasizes that all systems in nature are made with the same building blocks, according to the same rules. Differences in systems are due to the different organizations of building blocks. The course is organized in two parallel branches, one concerned with physical science and the other with biological science. The two branches are to be taught by two different teachers, working in parallel and often being together in the classroom for common discussions.

237. Passmore, J. *Outdoor Education in Canada -1972: an Overview of Current Development in Outdoor Education and Environmental Studies*. Canadian Education Association, 1972. 72 p.

Reviews trends and developments since 1969. The first half of the report traces the beginnings of outdoor education programmes in Canada; defines outdoor education together with its objectives and values; evaluates the use of a mobile classroom - primarily the school bus; lists examples of what teachers are doing to enrich their programmes in numerous disciplines, advises where to start a programme and whom to contact for voluntary assistance; enumerates special problems encountered in teaching out of doors, and presents reactions from involved individuals - pupils, teachers, parents and administrators. The second half is a resume of programmes, plans and problems in each of the provinces, followed by a sampling of special or unusual activities.

238. Peter, W.G. The American Institute of Biological Sciences joins others in search for interdisciplinary solutions to environmental problems. *Bioscience*, vol. 23, no. 7, July 1973, p. 448.

Describes results of efforts to seek meaningful ways of combining the knowledge and skill of different professions in alleviating environmental problems. An inter-society liaison committee on the environment was formed to implement the general philosophical goals of the American Institute of Biological Sciences.

239. Phenix, P. *Realms of Meaning*. New York, McGraw-Hill, 1964.

Analyses all knowledge into six basic categories: symbolics, empirics, ethics, aesthetics, synnoetics, and synoptics on the basis of the nature of the knowledge and the processes by which new knowledge is generated. Has interesting implications for all subject areas in education. Leads to the conclusion that science (empirics) should be taught as a unity and that the distinguishing features of science should be emphasized in curriculum development. Notes that the differences among the special sciences are differences of degree not of kind.

240. ———. Theoretical foundations for unified science education. In: *Unified Science Premises and Prospects*. Columbus (Ohio), Federation for Unified Science Education, 1975.

Presents in outline form some questions and/or issues to be resolved in the still developing theoretical basis for unified science education. Among the issues so presented are: Depth v. Comprehension, Closed v. Open, and Elite v. Commonwealth.

241. Poole, J. A survey of the content, course method and assessment procedures of some courses currently being taught. *School Technology Forum Working Paper No. 2*, p. 3-4.

A survey of thirty-seven technology-type syllabuses throughout the United Kingdom. A common denominator was found to be the involvement of project work. The most common mode of instruction was to teach the very basic facts traditionally or by the use of individual learning texts and to follow this with mini-projects, finishing with a large major project.

242. Pratt, A.L. Cluster core curriculums for E.E.E. *Junior College Journal*, vol. 41, no. 4, December/January 1971, p. 10-2.

The development of an interdisciplinary course in environmental and ecological education (EEE), and the construction of guidelines for a central theme for environmental occupations education were the major objectives of more than sixty educators attending the Ecological Technician Education Workshop.

243. Presst, B.M. Is school chemistry relevant? *Education in Chemistry*, vol. 7, 1970, p. 66.
244. Proceedings of the National Academy of Sciences. *Science: a Resource for Humankind*. Washington (DC), United States National Academy of Science, 1976. 87 p.
245. Projecto de Ciências Mobral/Funbec. (Available from Instituto de Física da USP. Caixa Postal 20516, Sao Paulo, Brazil.)

The Project has been designed for adults who have just gone through a literacy training programme, and comprises two units. The first one presents Electricity and the second Sanitary Education. The units are almost self-instructing and comprise written material and a simple experimental kit containing batteries, electric bulbs for a torchlight, a small model of a house made of cardboard, electric wires, a little microscope, precipitation flasks, etc. The unit of Electricity concerns the construction of the electrical network of a house and simple repairs thereof. The unit of Sanitary Education concerns the problem of verminosis. The students learn to recognize the causing agents of a few illnesses through practical activities with a small microscope, examining faeces and contaminated water.

246. Projektgruppe. *Integriertes Naturwissenschaftliches Curriculum (PINC): Naturwissenschaftlicher Unterricht und gesellschaftliche Arbeit*. Weinheim, Beltz-Verlag. (in press)

The first part of the book gives a characterization of the political situation in the Federal Republic of Germany as far as education and curriculum development are concerned. The major integrated science projects are classified and rated according to their aims and basic ideas. The second part describes the historical development of the natural sciences in relation to the development of technology and production with special emphasis on the social and ideological implications of this process. In part three, the basic principles and criteria for an integrated science curriculum are explained according to this view. Part four gives a detailed plan (about 100 pages) of the curriculum for grade 7 to 10, with two teaching units for grade 7 as specific examples. The last part contains didactic aids for the teacher.

247. Pukies, J. Emanzipatorischer Unterricht in den Naturwissenschaften. 1975, p. 19-36.

A description of the technical, social, political and ideological implications of the natural sciences and of the goals for science teaching contributing to an emancipation of the individual as well as of society as a whole.

248. Quadling, D.A. Mathematical/Science Links Committee new developments in school geometry. *Education in Science*, no. 44, September 1971, p. 20-5.

Discusses some of the aspects of geometry for exploring spatial relationships which have application in the fields of physics, chemistry and biology.

249. ———. Mathematics and school science? *Education in Science*, no. 64, September 1975, p. 19-20.

A commentary on three reports: Mathematics and School Chemistry; Mathematics for Biologists; and Mathematics Needs of A-Level Physics Students by the Chairman of the Schools Council Mathematics Committee.

250. Quiroz, C.A. Experimental Course of Integrated Science for Elementary School Teachers. (Document describing PRONAMEC, available from Project Headquarters, PO Box 3845, Lima, Peru)

251. Quitzow, W. Die integration Allgemeiner und beruflicher bildung im naturwissenschaftlichen unterricht. *Die Deutsche Berufs - und Fachschule?* no. 5, 1977, p. 361-6.
252. ———. Produktionsbezug - gemeinsame grundlage von arbeitslehre und naturwissenschaftlichen unterricht. *Die Deutsche Schule*, vol. 69, no. 1, 1977, p. 43-51.

Explains the interdependence of natural science, technology and production and why a natural science curriculum should be based on this insight. Gives the main principles for the selecting, weighting and structuring of the components of an integrated science curriculum according to this concept. Illustrated with some teaching materials.
253. ———. *Trendbericht Fachdidaktik Naturwissenschaften. betrifft. Erziehung* (in press).

A survey of the major integrated science projects and curricula that have been developed in the Federal Republic of Germany during the last five years. The projects are classified and rated according to their basic ideas, with special emphasis on the consideration of social implications of science and technology.
254. Ramsey, G. Assessing student progress in integrated science using teacher-prepared methods. In: Cohen, D. (ed.). *New Trends in Integrated Science Teaching* vol. IV, p. 79-94. Paris, Unesco, 1977.

In this paper on assessing student progress in science using teacher-prepared methods, emphasis has been placed in two main areas. The first is the conceptualization of assessment in terms intended to be useful to the teacher. The second is the clear identification of assessment of students as much more than pencil-and-paper tests and the outlining of a few areas which teachers may explore.
255. Raw, I. The integration of nutrition education in the basic biomedical science. *American Journal of Medical Education*, vol. 52, 1977, p. 654.
256. ———; Rockwell, P. Health and science education: a natural partnership. *Principal*, vol. 57, no. 3, 1978, p. 85-90.
257. Raw, I. et al. What people eat: a chemistry program based on nutrition. *Journal of College Science Teaching*, vol. 4, no. 3, January 1975, p. 177-8.
258. Reay, J.F. (ed.). *Integrated Science and Teacher Education*. St. Augustine, Trinidad, Unesco/University of the West Indies, 1974. 238 p., appendices.

The report of a Unesco/CEDO Caribbean workshop in Barbados, October 1973. Part 1 describes the way in which the workshop was conceived and outlines the movements in science education in the Caribbean. There is a set of recommendations for future development. Part 2 is a collection of plenary papers together with the views of participants in working groups which dealt with the topics of the plenary sessions. An unusual feature of the working groups was job cards which guided the deliberations, and these are given as appendices to the report. Part 3 consists of resource materials and models for teaching units for primary, junior secondary and upper secondary levels.
259. ———. Examining Caribbean Integrated Science: Some Proposals. Paper presented at a meeting of the Caribbean Regional Organization of Associations for Science Education, Trinidad, April 1976. (Available School of Education, University of the West Indies, St. Augustine, Trinidad).

The author suggests that the CXC provide a profile of the candidate, rather than the pass/fail in particular subjects and that the examination papers examine broad issues, and place greater stress on the major concepts and principles of science than the GCE.

260. ———. Summative evaluation of Caribbean integrated science projects. In: Cohen, D. (ed.). *New Trends in Integrated Science Teaching*, vol. IV, p. 142-51. Paris, Unesco, 1977.

The major strategy for summative evaluation of the several integrated science projects was based on an educational experiment and upon achievement tests. Other forms of evaluation were also used. The author suggests that there is little evidence that data generated from the evaluation were used by the decision-makers and that decisions are made on the basis of availability of published materials and individual appraisal of these. Suggests that teacher education courses should make teachers more aware of the significance of evaluation data.

261. Řeháček, Z. Thirteen Years of the Czechoslovak Longterm Postgraduate Training Courses, Unesco, on Modern Problems in Biology. Available from the Institute of Microbiology, Czechoslovak Academy of Sciences, Prague, Czechoslovakia.

Describes a one-year post-graduate course in microbiology. The programme involves a three-month practical course followed by a nine-month period of work at Czechoslovak research institutions. Practicum may be selected in one of several themes. The course is accompanied with lectures and seminars on the present state and future prospects of research in the basic branches of biology.

262. Reid, O. The science curriculum in the primary school in Tasmania. *Education News*, vol. 11, April 1967, p. 7-9.

The author outlines the broad general aims for teaching science at the elementary level. He describes how science is primarily concerned with tangible things in that it uses the immediate environment as the prime source of information. The general approach is one of direct experiencing. Suggestions are given for implementing this approach in schools in Tasmania.

263. Renaud, J.W. Scientific separatism. *Journal of Geological Education*, September 1971.

Reviews very generally the desirability of college science departments redirecting some of their efforts towards interdisciplinary goals, and proposes second-level courses given through the combined efforts of several science departments.

264. *Report and Proceedings of the Natural Resources and Conservation Education Conference*. Lusaka, May 28-30, 1970. Lusaka, University of Zambia.

An African conference on environmental education with some worldwide themes included such topics as: integrated science teaching; existing or planned programmes on natural resources and conservation education in Africa; programmes for teacher education, as well as primary, secondary and adult education; report on the formulation of conservation principles; report on ways and means for environmental education; and conservation activities in Zambia.

265. *Reports of the School Technology Forum*. (Available from the National Centre for School Technology, Trent Polytechnic, Nottingham NG1 4BU, United Kingdom).

Quarterly reports enabling practising teachers to take part in and be informed about curriculum development in the field of school technology. Membership in the Forum is open to nationally-based subject and professional teachers' associations and regional organizations concerned with technology in schools such as local science and technology centres and informal groups of interested teachers.

66. Rhyner, C.R. et al. The Chemistry-Physics Program at the University of Wisconsin-Green Bay. *American Journal of Physics*, vol. 42, no. 12, December 1974, p. 1106-11.

Presents the objectives, content structure, and administrative procedures of an integrated chemistry-physics programme. Considers the relative advantages and disadvantages of an integrated approach.

67. Richards, C.; Abell, B. Science 5/13: an evaluation of an evaluation. *School Science Review*, vol. 54, no. 188, March 1973, p. 579-87.

Discusses the course evaluation made by the Science 5/13 project team. Illustrates some of the complexities and problems of all curriculum evaluation.

68. Richmond, P.E. Approaches to integrated science teaching. *School Science Review*, vol. 55, no. 192, March 1974, p. 591-5.

Summarizes the reasons for the increasing interest in integrated science. Identifies a number of related approaches such as general science, co-ordinated science, interrelated science, interdisciplinary or unified science and undifferential science as well as the process approach, the environmental approach and the use of projects.

69. ———. (ed.). *New Trends in Integrated Science Teaching* Vol. I, Paris, Unesco, 1971. 381 p.

The articles in this volume, commissioned or collected internationally, attempt to define and illustrate integrated science teaching.

70. ———. *New Trends in Integrated Science Teaching* Vol. II, Paris, Unesco, 1973. 239 p.

This volume contains nine commissioned articles and gives examples of integrated science projects world-wide.

71. ———. *New Trends in Integrated Science Teaching* Vol. III, Paris, Unesco, 1974.

The report of the ICSU Conference on Teacher Education for Integrated Science, University of Maryland, April 1-10, 1973.

72. Ridky, R.; Smith, S.C. Considering the commonplace: a historical note. *The Science Teacher*, vol. 42, no. 2, February 1975, p. 42-3.

Describes the Cornell nature study movement developed in 1897 which has contemporary significance in that it was an interdisciplinary approach to teaching science based on leaflets published quarterly on natural history. Has significance mainly for secondary school science.

73. Roberts, G. The cemetery - setting for multidisciplinary learning. *The Science Teacher*, vol. 41, no. 4, April 1974, p. 43-4.

Describes how a cemetery can provide a multidisciplinary learning experience for students and can lead to the discovery of many concepts in human ecology.

274. *The Role of Geography in Environmental Education*. London, The Geographical Association, Standing Committee for Environmental Education, 1974.

275. Romey, W.D. Transdisciplinary, problem-centred studies: who is the integrator? *School Science and Mathematics*, vol. 75, no. 1, January 1975, p. 30-8.

Outlines the basic requirements for what the author feels are genuinely transdisciplinary studies. Describes ways of transcending the boundaries of the disciplines and describes a learning environment that would facilitate integration.

276. Rosen, L. Science and society: a complex interaction. *Physics Teacher*, vol. 11, no. 6, September 1973, p. 329-39.

277. Russell, H.R. Co-ordinating science and other subjects. *Nature Study*, January 1975.

This article presents examples of science units which have become successful multidisciplinary projects. Included are a protect your environment campaign and hunger day. Pre- and in-service courses, file of references, and resource people are suggested as being helpful in structuring interdisciplinary activities. Ideas and sources for projects are mentioned.

278. Ryan, F.L. Science and the humanities: a heuristic approach. *Science Education*, vol. 56, no. 2, April/June 1972, p. 243-50.

Describes one of the units from an interdisciplinary programme where students and faculty from diverse disciplines examine ideas and materials and discover underlying unity of concepts. This article discusses the theme of 'structure' in science, the humanities, and literature.

279. Saul, G.M. Industrial chemistry. *Education in Science*, no. 44, September 1971, p. 31-2.

Describes a course offered by the Industrial Chemistry Department at Brunel University in Middlesex. Provides a broad training based on chemistry to fit a student to enter a wider range of careers. Subsidiary topics are headed by technological economics.

280. Sayer, M. Technology appreciation. *School Science Review*, vol. 54, no. 189, June 1973, p. 795-7.

Suggests that the cause of technology in school might best be served by a programme of studies aimed at appreciation of, as well as involvement in, the efficient use of resources, whether material, economic or social.

281. Schaefer, G.; Kattmann, U. IPN Unit Bank Biology - a new type of biology curriculum. *Journal of Biological Education*, vol. 10, no. 5, October 1976, p. 242-8.

IPN in Kiel has developed single curriculum units each intended to occupy 10-15 lessons, and constructed in such a way that they may be placed in several possible positions in the curriculum. Unit Bank Biology has been developed on the basis of a three-dimensional pattern of reasoning, in which, besides the dimension 'structure of the discipline', equal importance is accorded to the dimensions 'social relevance' and 'students' interests'. Biology is regarded as a science of biosystems in general extending from biochemistry to

social science and psychology. Integrative teaching is a main theme in the curriculum.

282. Schatz, V.; Schatz, A. How soils are formed and become fertile: an example of an integrated science unit. *School Science and Mathematics*, vol. 72, no. 6, June 1972, p. 484-90.

Describes an activity based unit for secondary schools in which many science disciplines are merged for instructional purposes.

283. Schmieder, A.A. The nature and philosophy of environmental education: goals and objectives. In: Aldrich, J. (ed.). *Trends in Environmental Education*, p. 23-34. Paris, Unesco, 1977.
284. Schoer, G. The integration of the sciences and implications for interdisciplinary studies and environmental education. *A Science Bulletin for Teachers in Secondary Schools*, no. 19, 1974.

The author examines the whole concept of secondary school integrated science. The rationale for such studies and current integrated curricula in England and the United States are discussed. Difficulties with such studies and with teacher training programmes are examined. The progress of integrated science in Australia is mentioned.

285. Schoof, J. (ed.). *Neue Curricula in den Naturwissenschaften*. Hanover, Schroedel-Verlag, 1973.

A description of the different American and British projects that have influenced curriculum development in the Federal Republic of Germany.

286. Schools Council. *Science 5/13*. London, Schools Council Project Information Centre, June 1972 (SC-05-01). 3 p.

An information sheet describing the Science 5/13 programme. It lists the materials and discusses the evaluation and training phases of the programme.

287. *School Technology Forum Working Paper No. 1*. Nottingham, Trent Polytechnic, February, 1973. 15 p.

Presents a detailed statement of a consensus of national opinion in the United Kingdom about the objectives and methods of technology in schools. The ways and means for new progress are spelt out.

288. *School Technology Forum Working Paper No. 2*. Nottingham, Trent Polytechnic, January 1975. 34 p.

An interim report on the activities of the Forum's Curriculum Working Party, with special reference to the conference held in the fall of 1974.

289. Schwartz, A.T. Provocative opinion: the humanity of chemistry. *Journal of Chemical Education*, vol. 51, no. 3, March 1974, p. 172-4.

Presents some instances of the implications of chemistry which illustrate both its scientific and humanistic nature. Indicates that chemistry can be used as a bridge to span the artificially created chasm between Snow's two cultures and thus to demonstrate the fundamental unity of all knowledge.

290. Schwartz, J.; Ragir, S. Evolution from two perspectives: an interdisciplinary course in physics and anthropology. *American Journal of Physics*, vol. 42, no. 4, April 1974, p. 274-7.

Discusses an interdisciplinary course offered to senior students in physical, biological, and social sciences, with emphasis on explaining the character of scientific work and the mechanisms underlying biological evolution. Included in a bibliography of available materials.

291. Scientific Committee on Problems of the Environment. *Environmental Issues 1976*. Washington (DC), International Council of Scientific Unions, 1976. 86 p.

292. Segal, E.M. Understanding our world. In. *Unified Science Premises and Prospects*. Columbus (Ohio), Federation for Unified Science Education, 1975.

Describes the major stages in the advance of science as it has provided increasingly abstract yet verifiable ways of understanding the great variety of natural phenomena. Emphasizes the unity of the scientific endeavour. Proposes that many scientists may not understand the nature of science even though 'doing' science is their profession.

293. ———, McCain, G. *The Game of Science*. Belmont (Calif.), Brooks/Cole, 1969.

Provides a comprehensive and specific overview of the nature of science as a human endeavour to explain natural phenomena. Written in a lively and non-technical style, it identifies, describes, and gives examples of how science is done by scientists along with some of the principal 'girders' in the structure of science.

294. *Seminar on the Training of Teachers by the Interdisciplinary System, to Use this System in Schools. Final Report*. Paris, Unesco, 1970.

Report of a conference sponsored by Unesco at Bouake, Ivory Coast, in 1970. The conference was attended by teacher educators from primary teacher training colleges. Topics of the conference included environment and environmental studies; how to conduct environmental studies; and environmental studies and teacher training.

295. Showalter, V. *Toward a Unified Science Curriculum*. Cleveland (Ohio), Educational Research Council of America, 1971. (ERC Papers in Science Education, 17.)

Describes reasons why a unified science approach is more flexible and therefore more appropriate for meeting the changing and yet unpredictable needs of schools and learners in the future than is either of the two usual approaches to curriculum change - textbook revision and national curriculum project. Describes desirable features of the idealized unified science curriculum.

296. ———. *Unified Science Education Programs and Materials*. Columbus (Ohio), Center for Science and Mathematics Education, Ohio State University, 1973.

This publication provides a current listing and description of programmes, student instructional materials, and related literature in the field of unified science education. In Part I, international unified science programmes are presented alphabetically by country, followed by United States programmes listed by state. Each programme description includes a concise abstract, the grade level range over which it operates, the instructional format and availability, the programme type, the year in which the information was obtained, and names and addresses of the authors. Part II consists of abstracts of student instructional materials related to unified science education, and Part III is an annotated bibliography of the related literature. In addition to abstracts of the material, these

sections provide information regarding the publisher, date of publication, number of pages, reference numbers for retrieval, and the source and cost of copies of the documents.

297. ————. Desirable characteristics of teachers of integrated science. In: Richmond, P. (ed.). *New Trends in Integrated Science Teaching*, vol. III p. 20-5. Paris, Unesco, 1974.
298. ————. Rationale for an unbounded science curriculum. *School Science and Mathematics*, vol. 75, no. 1, January 1975, p. 15-21.

Presents the present status of unified science education and provides a pragmatic, philosophical and psychological rationale for this approach.
299. ————. Unified science education - today and tomorrow. In: Showalter, V. et al. (eds.). *Unified Science Premises and Prospects*. Columbus (Ohio), Federation for Unified Science Education, 1975. 107 p.

Summarizes the trends in the development of the unified science concept especially as it has application in local curriculum development in the United States. Identifies directions and probable problems for the future extension of these trends.
300. ————. (ed.). *Abstracts of Unified Science Programs*. Columbus (Ohio), Federation for Unified Science Education, 1976. 55 p.

A detailed abstraction of unified science programmes worldwide compiled at the FUSE Center, Columbus, Ohio.
301. ————. *What is Unified Science?* Columbus (Ohio), Federation for Unified Science Education, 1978.

A composite of pertinent articles related to the philosophy and rationale for unified science, discussion of scientific literacy, examination of the FUSE model for unified science curriculum development, and discussion of how to begin a unified science course.
302. ————; Thomson, B. The modular unit. *Prism II*, Columbus (Ohio), FUSE Center, Autumn 1975.

Describes a unique plan for assembling unified science units of instruction by using components selected from existing materials including both text and non-text sources. In effect, enables local teachers to organize locally meaningful units without having to be expert writers. The plan and techniques recommended have potential implications for all subject areas since several universal psychological principles are incorporated in the design.
303. ————; ————. Getting into unified science. *Prism II*, Columbus (Ohio), FUSE Center, Autumn 1976.

Describes procedures and plans for enabling local groups of science teachers to implement unified science concepts into the local science programme. Describes two basic approaches - 'unit-at-a-time' and 'year-at-a-time.' Describes four different formats for unit design and six stages of the overall development process.
304. ————; Cox, D.; Holobinko, P. Characteristics of the unified science unit. *Prism II*, Columbus (Ohio), FUSE Center, Autumn 1973.

Presents a set of sixteen guidelines that specify ideal characteristics for a unified science unit of instruction and the rationale on which these guidelines are based. Developed on the basis of actual experiences in designing and teaching such units accumulated by the members of the Federation for Unified Science Education (FUSE).

305. ———. et al. Program objectives and scientific literacy. *Prism II*, Columbus (Ohio), FUSE Center, Spring and Summer 1974.

Provides a working definition for 'scientific literacy' in terms of seven dimensions. Each dimension is further explicated by a set of ten to twenty factors. Based on a study of existing literature and the premise that the aim of science teaching in the schools is to enable all students to achieve satisfactory levels of scientific literacy. Has direct implications for evaluation and programme development at all grade levels for all sciences.

306. Sim, W.K. Evaluation of integrated science teaching in Malaysia. In: Cohen, D. (ed.). *New Trends in Integrated Science Teaching*, vol. IV p. 171-85. Paris, Unesco, 1977.

Describes the problems of evaluating integrated science teaching against a complex background of national pedagogical reform and of changes in society.

307. Siu, R.G. Science and contemporary problems. In: Showalter, V. et al. (eds.). *Unified Science Premises and Prospects*. Columbus (Ohio), FUSE Center, 1975.

Describes the contributions of science to society, higher order effects of science and its impact on society, and a proposed post-graduate course in Unified Science Education in the light of the previous considerations. Emphasizes that the solution of human problems requires application of science without respect to the boundaries among the various sciences.

308. Springer, M.A. Role of science in the English class. *English Journal*, vol. 65, October 1976, p. 35-6.

309. Sutton, C. What skills are needed to teach integrated science, and how can their development be monitored? In: Cohen, D. (ed.). *New Trends in Integrated Science Teaching*, vol. IV, p. 53-64. Paris, Unesco, 1977.

This paper is mainly for those decision-makers who are in a position to assist the growth of a more skilful teaching community and who therefore need information about current levels of skill. It assumes that teacher skills are at least as important as curriculum materials and discusses ways of identifying those skills that are particularly required for an innovative programme in integrated science. Trends in the demands made upon integrated science teachers are surveyed and suggestions made for improving the flow of feedback to the decision-makers.

310. Taffe, W.J. Topics in the natural sciences. *Journal of College Science Teaching*, vol. 5, no. 2, November 1975, p. 121.

Describes a natural science programme that offers twenty-five or more different topics each semester. Presents examples of the topics available and outlines the advantages of this approach.

311. Tamamushi, B.; Ohashi, H.; et al. Survey on Basic Principles of Integrated Science Teaching. March 1975. (Available from the National Institute for Educational Research, Tokyo, Japan)

Comprehensive report on the lectures given at a series of meetings held by the National Institute for Educational Research in 1974-5. Topics included. (1) a survey of the history of integrated science teaching in Japan; (2) philosophy and principles of integrated science teaching; (3) how to deal with the history of science in integrated science teaching; (4) training of teachers for integrated science teaching; and (5) plans for an integrated science course.

312. Tamamushi, B. Science and Humanity - on the Modernization of Science Teaching. January 1977. (Available from the National Institute for Educational Research, Tokyo, Japan)

The modernization of science education, while answering the social need and the scientific development, aims to increase the understanding and the familiarity of students to science through the careful selection and presentation of teaching materials. Principles of humanistic education should be respected in science education. To this end, teachers of all subjects should co-operate.

313. ————. Integrated Science and the History of Science. March 1977. (Available from the National Institute for Educational Research, Tokyo, Japan)

Advantages and difficulties of introducing historical developments of science into education are discussed. The advantages of this approach in integrated science are emphasized, and it is recommended that teachers have some knowledge of the historical background of important developments in science. Examples are given.

314. Tammadge, A.R. Moves towards mathematics and science links. *Education in Science*, no. 44, September 1971, p. 17-9.

A report of a conference held at Oxford to identify the areas of conflict when topics involving science and mathematics overlap, to suggest solutions to the difficulties and to establish working parties which will further the investigations concerning linkage of science and mathematics.

315. Tawney, D.A. Technology in the Nuffield Advanced Science Projects. *School Science Review*, vol. 54, no. 187, December 1972, p. 365-71.

Explores what technology means in the school science curriculum and examines the place that the Nuffield A-Level projects have given to it.

316. ————. The evaluation of integrated science education - its strengths and limitations, its scope and methodology. In: Cohen, D. (ed.). *New Trends in Integrated Science Teaching*, vol. IV, p. 16-25. Paris, Unesco, 1977.

Evaluation is undertaken to improve education, to reassure and, regrettably, because it is currently fashionable. Its strengths come from separating information-providing and option-probing from decision-making rôles. Its limitations come from the over-expectation it so often produces. The areas about which information should be provided include context, aims, processes and effects. Its methodology needs to be wide-ranging and is likely in practice to lie between the descriptive and quantitative extremes described.

317. Thier, H.D. Content and approaches of integrated science programs at the primary and secondary school levels. In: Richmond, P.E. (ed.). *New Trends in Integrated Science Teaching*, vol. II, p. 53-70. Paris, Unesco, 1973.

Surveys the aims and objectives of a number of primary science programmes throughout the world, defining areas of commonality and of difference.

318. ———; Hadary, D. We can do it too. *Science and Children*, vol. 11, no. 4, December 1973, p. 7-9.

319. Thomson, B. FUSE and the Center for Unified Science Education. *School Science and Mathematics*, vol. 75, no. 1, January 1975, p. 109-14.

Describes the function and activities of the Center and outlines the curriculum methodology advocated by the Center. The latter is based on development of instructional units by the local science teachers for use in the local school(s) and is applicable at all grade levels K-12.

320. Thompson, L. International environmental problems. *International Educational and Cultural Exchange*, vol. 7, no. 1, Summer 1971, p. 61-6.

A small group of faculty members at the University of Colorado volunteered to organize an experimental interdisciplinary course which would attract students from many countries. This article relates how the course was planned and how the students evaluated the benefits they received. Twenty-five students from fifteen different countries were enrolled in this course.

321. Tinsley, I.J. *Evaluation of an Introductory College Course in Environmental Studies: Final Report*. Corvallis, Oregon State University, Department of Agricultural Chemistry, 1972. 63 p.

Reports an evaluation conducted on 'Man and the Environment'. The course content was integrated and an interdisciplinary team of teachers used several innovative approaches. The students were administered tests entitled an Environmental Knowledge Inventory and the Inventory of Societal Issues (ISI), both before and after the course. Results indicated that students taking the course increased their knowledge of the environment significantly when compared with a control group; they also showed significant attitude changes for four of the five factors on the ISI scale. These changes are interpreted to mean that the students have become less sure that scientific and technological advances are beneficial to the man-nature interaction, and they have become more aware of the complexity of the problems; they are more concerned with the problems of population growth and the need to restrict it; they are less certain that science and technology are capable of solving society's problems; and they are more concerned with individual and personal responsibility and action.

322. Turner, A.D. Nuffield Science Uses Mathematics Continuation Project. *Education in Science*, no. 66, January 1976, p. 17-8.

Outlines some of the basic problems facing science teachers when using modern science curricula demanding mathematical ability on the part of the pupil. Briefly describes the endeavours of Project SUM to produce modules which are elaborations of certain mathematical topics which occur in the common science curriculum projects for pupils aged 11-16 years.

323. Unesco. *Enseñanza Integrada de las Ciencias en América Latina 2*. Montevideo, Unesco, 1976. 68 p., annexes.

Report of a seminar in Uruguay in November 1975. (In Spanish.)

324. ———. *Intergovernmental Conference on Environmental Education, Tbilisi U.S.S.R., 14-26 October 1977: Final Report*. Paris, Unesco, 1977. 32 p.

325. ———. RECSAM. *Integrated Science Teaching in Asia*. Paris, Unesco. 102 p.

Report of a workshop held in Penang, Malaysia, July - August 1972.

326. Vinson, J.S. Toward the year 2000: an interdisciplinary course on the future. *Journal of College Science Teaching*, vol. 5, no. 1, September 1975, p. 29-30.

Describes a futures course which is part of a large humanities course required of all undergraduates.

327. Warpinski, R. *A Supplementary Program for Environmental Education, Art, Grade K-3*. Green Bay (Wisc.), Project Instruction-Curriculum-Environment, 1972, 76p.

Presented in this teacher's guide for kindergarten through to grade 3 are lesson plans and ideas for integrating art and environmental education. Each lesson originates with a fundamental concept pertaining to the environment and states, in addition, its discipline area, subject area and problem orientation. Then behavioural objectives and learning experiences are outlined. Space is provided for teachers to note resource and reference materials - publications, audio-visual aids, and community resources. The guides are designed to supplement existing course content at appropriate times.

328. ———. *A Supplementary Program for Environmental Education, Art, Grade 10-12*. Green Bay (Wisc.), Project Instruction-Curriculum-Environment, 1972, 88 p.

Presented in this teacher's guide for grades 10-12 are lesson plans and ideas for integrating art (drawing, painting, graphics, photography and commercial art) and environmental education. Each lesson is based on a fundamental concept relating to the environment and is accompanied by an explanation of its discipline area, subject area and problem orientation. Behavioural objectives and suggested learning experiences are outlined.

329. ———. *A Supplementary Program for Environmental Education, Industrial Arts, Grade 7-12*. Green Bay (Wisc.), Project Instruction-Curriculum-Environment, 1972, 76p.

Presented in this teacher's guide for grades 7-12 are lesson plans and ideas for integrating industrial arts (draughtsmanship, woodworking and metalworking) and environmental education. Each lesson is based on a fundamental concept relating to the environment and is accompanied by an explanation of its discipline area, subject area and problem orientation. Behavioural objectives and suggested learning experiences are outlined.

330. Watson, F. (ed.). *The Social Impact of Modern Biology*. London, Routledge & Kegan Paul, 1971.

331. Webb, L.F. Measuring, science and history: time-line problems. *Arithmetic Teacher*, vol. 24, February 1977, p. 115-16.

332. Webb, N. Correlating the teaching of mathematics and science. *Int. J. Math. Education, Science Technology*, vol. 6, 1975, p. 105-10.

333. Webb, W.G.G. Developing a good relationship between mathematics and science. *School Science Review*, vol. 54, no. 188, March 1973, p. 441-9.

Describes the co-operative activities between the department of mathematics and those of physics, chemistry, biology, technology, geography, economics, business studies and commerce at Oakham School.

334. Welch, W.W. Evaluation and decision-making in integrated science. In: Cohen, D. (ed.). *New Trends in Integrated Science Teaching*, vol. IV, p. 26-36. Paris, Unesco, 1977.

Curriculum developers, teachers and funding groups face a number of decisions concerning integrated science. Providing information to assist in these decisions is the function of evaluation. This paper identifies several key decisions and the evaluation literature pertaining to these decisions is reviewed.

335. Wheatley, J.H.; Coon, H.L. (eds.). *100 Teaching Activities in Environmental Education*. Columbus (Ohio), ERIC Information Analysis Center for Science, Mathematics and Environmental Education, 1974. 204 p.

This package contains over 100 activities in environmental education designed for students from kindergarten through grade 12. Each activity has been classified by the editors according to the most appropriate grade level, subject matter, environmental concept involved and environmental concept area. Subject areas are science, mathematics, social studies, language arts, and fine arts. Environmental concepts include bio-physics, socio-cultural, management and change; and problem areas are aesthetics, health, genetics and physiological/behavioural. In addition to being classified into these four categories, each activity contains: (a) a statement of purpose on how the activity may be used; and (b) a reference to a source where the activity may be found in more detail or with variations.

336. Williams, A.B. The Three Phase Primary Science Project in Papua New Guinea. Paper presented at Seminar on Teaching-Learning Strategies and Educational Planning, IIEP, Paris, March 1976. 34 p.

Describes the TPPS project from inception to dissemination with particular attention to the teaching-learning strategy advocated.

337. Williams, R.B. A method of integrating chemistry subject matter into biological science instruction. *Science Education*, vol. 59, no. 2, April/June 1975, p. 167-75.

338. Wixom, C.W. USMES: a reality-oriented approach to elementary education, Unified Science and Mathematics for Elementary Schools. *Education Digest*, vol. 40, September 1974, p. 25-8.

339. Wolman, M.G. Interdisciplinary education: a continuing experiment. *Science*, vol. 195, 25 November 1977.

Describes insights gained at Johns Hopkins University in developing and maintaining interdisciplinary courses and programmes at the graduate level. These insights range from rationale ('problems in the real world are not separable into disciplines') to size of faculty devoted to a given programme (at least ten but less than twenty).

340. Wolsk, D. Methodologies of environmental education. In: Aldrich, J. (ed.). *Trends in Environmental Education*, p. 35-48. Paris, Unesco, 1977.

341. Woods, F.H.; McCurdy, D.W. An analysis of characteristics of self-directedness as related to success in an individualized continuous progress course in chemistry and physics. *School Science and Mathematics*, vol. 74, no. 5, May-June 1974, p. 382-8.

Reports data on 135 students completing the first year of the Nebraska Physical Science Project (NPSP). Those students who were most successful in this integrated and

individualized course perceived themselves as being well able to direct their own activities with a minimum of outside supervision.

342. Woolnough, B.E. The mathematics-physics interface in school. *Physics Education*, vol. 10, no. 3, March 1975, p. 90-2.
343. ———. The place of technology in schools. *School Science Review*, vol. 56, no. 196, March 1975, p. 443-8.

Seeks to clarify some of the issues relating to the place of technology in schools and suggests a practical, pragmatic approach for its implementation.
344. ———. A fresh look at some current myths. *Education in Science*, no. 66, January 1976, p. 18-19.

Compares the external examination entries of GCE and CSE for science in the years 1968 and 1973. Evidence indicates a move toward students taking combined sciences in the first two years of secondary school followed by a reversion to separate sciences for the 14-16 year olds.
345. Yager, R.E. New views for developing science curricula. *The Australian Science Teachers Journal*, vol. 18, December 1972, p. 17-23.

Stresses the need for experts in the natural and social sciences to work together. Cites nine priorities to consider in developing science curricula for the coming decade. Emphasizes the importance of science in general education and the need for that science to be humanly relevant and socially oriented.
346. Yao, K.Y.B.; Kelly, E.A. Integrating science with the creative arts in career education. *Science and Children*, vol. 13, no. 3, November 1975, p. 22-4.
347. Yates, A.J. *Plastics - an Integrated Approach*. Maidenhead (Berks), Edward Arnold, 1975. 58 p.

A complete mini-course designed for use with non-examination pupils in middle or secondary schools. Text includes theory, practical work and a variety of exercises. (Review by M.F. Tomlinson in *School Science Review*, vol. 57, December 1975, p. 404.)
348. Yoloye, A. Evaluation of the African Primary Science Programme (APSP). In: Cohen, D. (ed.). *New Trends in Integrated Science Teaching*, Vol. IV, p. 131-42, Paris, Unesco, 1977.

Description of efforts in curriculum programme evaluation with respect to a primary school science programme (APSP) which operated in more than ten African countries. The evaluation programme was as much an experimental programme as the science programme itself.
349. Young, B.L. Primary science in Africa. *School Science Review*, vol. 55, no. 190, September 1973, p. 16-25.

Outlines the curriculum development programme in progress at Ahmadu Bello University, Zaria in northern Nigeria. Provides background information on the teachers, the children and the schools. Briefly describes the materials developed to date.
350. ———. Some general considerations. *Journal of the Ghana Association of Science Teachers*, vol. 16, no. 1, June 1976, p. 5-8.

Makes the point that every teacher is to some extent his own curriculum planner and the classroom teacher is the main instrument of curriculum change. The author feels that the science teacher associations have a key role in spreading new ideas. They must stimulate the teacher-training institutes to provide necessary pre-service and in-service training in the new programmes. As far as major projects are concerned, science teachers associations can act as a catalyst in initiating needed projects, be formally represented on curriculum committees developing and evaluating the materials, and generally monitor the whole project.

351. ————. Towards a Process Approach in primary science. *Science Teachers' Association of Nigeria Journal*, May 1974.

Explores the rationale behind the trend away from topic/content primary science towards concept and process based curricula. Outlines the 'process' philosophy established by the Nigerian Educational Research Council and describes how this philosophy has been translated into curriculum materials.

352. Young, D. Science and values belong together. *Journal of College Science Teaching*, November 1974.

Describes two science courses based on the premise that value judgements ultimately bring the sciences 'to life'. The courses integrate science knowledge with the ethics that may effect how the knowledge can and should be used.

353. Zahlebyj, A.N. On the system of environmental education in the general school. *Sovetskaja Pedagogika*, no. 10, 1972, p. 57-66.

The first part presents a brief outline of the state of nature protection at the international level and its development trends. The second part deals with environmental education in the general school. The author points out that since the early sixties laws on the safeguarding of nature have been adopted throughout the Soviet Union, and the schools have complied by introducing the protection of all basic natural resources into the programmes and textbooks of such subjects as biology, chemistry, geography, etc. The conclusion draws attention to the necessity of building up and developing a system of environmental education in the general school and presents what are considered to be main directions of educational research in this area.

354. Zander, A.R. Science and fiction: an interdisciplinary approach. *American Journal of Physics*, vol. 45, no. 1, January 1975, p. 9-11.

Describes the objectives, structure, and evaluation of an upper level, limited enrolment, elective course taught by a team of a physicist, a psychologist, and a literary scholar. Reports experience with the course since first taught in the spring of 1972.

355. Zimmer, G.P. Personal reflections on science and social science. *Social Education*, vol. 41, February 1977, p. 128-31.

356. Zvi, N.B., Novick, S. A model for change and flexibility in curriculum development: evolution of the CMS Chemistry Program. *School Science and Mathematics*, vol. 77, no. 1, January 1977, p. 59-65.

Traces the evolution of procedures designed to involve practising teachers in a way leading to a more flexible learning programme. Curriculum used as a model in this procedure is the socially-oriented Chemistry in Modern Society (CMS).

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358. Alkin, M.C. Products for improving educational evaluation. *Evaluation Comment*, vol. 2, no. 3, September 1970.
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360. ———; NASDTEC. *Guidelines and Standards for the Education of Teachers of Science and Mathematics*. Washington, AAAS, 1971, 77 p.
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363. Atkin, J.M. *Journal of Research in Science Teaching*, vol. 5, p. 338.
364. Baez, A.V. (ed.). *New Trends in the Utilization of Educational Technology for Science Education*. Paris, Unesco, 1974.
365. Ben-Zvi, R. (ed.) [Chemistry for High School.] Rehovot, Weizmann Institute of Science, 1972. (In Hebrew).
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Appendix III. Contributing authors— Biographical notes

PHILIP ADEY, Centre for Science Education, Chelsea College, University of London, 90 Lillie Road, London SW6, United Kingdom

He worked in the Caribbean as teacher and project leader for eleven years. Since 1974 he has been based at Chelsea College, researching Piagetian science concept development in the United Kingdom and West Indies. He has also been involved in teacher education and textbook production in Botswana, Lesotho and Swaziland.

PROFESSOR RAIS AHMED, Vice-Chancellor, University of Kashmir, Srinagar, Kashmir, India

Working to bring about greater integration in postgraduate science through courses and seminars in which participants from various departments are concerned with a problem, he is also organizing research on applied problems of regional development by co-operation of multidisciplinary teams. Field studies and projects with students drawn from different departments are an interest.

PROFESSOR UBIRATAN D'AMBROSIO, Director, Instituto de Matemática, Estatística, e Ciência da Computação, Universidade Estadual de Campinas, Caixa Postal 1170, 13 100 Campinas, São Paulo, Brazil

He is also director of the Multinational Project for the Improvement of Science Education (sponsored by the OAS and the Brazilian Ministry of Education) and vice-president of the Interamerican Committee on Mathematical Education. He has been a visiting instructor at the Centre Pédagogique Supérieur in Bamako (Mali) and director of Post-graduate Studies in Mathematics and Natural Science at the State University of New York, Buffalo. He is especially interested in the adaptation of educational structures to the real needs of developing countries.

DR SAM 'TUNDE BAJAH, Senior Research Fellow, International Centre for Educational Evaluation, University of Ibadan, Ibadan, Nigeria

Educated at the University of Ibadan, Oxford University and the University of South Dakota, he has co-authored an integrated science book and others in chemistry. As an executive member of STAN, he acts as Editor-in-Chief of the STAN Journal.

DR PAUL A. BECHT, Associate Professor, P.K. Yonge Laboratory School, University of Florida, Gainesville, Florida 32611, United States

He is currently teaching integrated science in middle and high school, and continuing the development of the Aviology Concept Program. He is Director of the Aviation Education Resource Center at Florida, and involved in research concerning the use of Cognitive Style Mapping in understanding learner differences, and in research on curriculum development, dissemination and modification.

NORMAN BOOTH, 104 Moss Lane, Sale, Cheshire M33 5BZ, United Kingdom

Recently retired as Staff Inspector, he has been involved in most English science curriculum development in various capacities. His career has included school teaching, army service as a major, and Her Majesty's Inspector.

DR. CHEONG SIEW YOONG, Deputy Dean, Faculty of Education, University of Malaya, Kuala Lumpur, Malaysia

Educated in Singapore and the United States, Dr. Cheong has taught in secondary schools in Malaysia and has for many years been training graduate science teachers at the University of Malaya. She has been a consultant to the Malaysian Ministry of Education in various projects concerned with science curriculum development and evaluation. Her current research interest is the evaluation of new integrated science curricula as well as with the development of resources for the preparation of science teachers. She is Vice-President of the Malaysian Association for Science and Mathematics Education and Director of the Asian Association for Biology Education.

DR. NELIS A. VAN DER CINGEL, Biologisch Centrum, Afd. Didactiek, Rijksuniversiteit Groningen, Kerklaan 30, Postbus 14, Haren (Gr.), Netherlands

Head of a Teacher Education Department in Groningen University (subfaculty Biology), he also advises on the restructuring of the curricula for teacher training in the universities of the Netherlands. He is involved in research on cognitive development of biological concepts (animal behaviour) and on integrated science education.

GEORGE O. DAWSON, Associate Professor of Science Education, Florida State University, Tallahassee, Florida 32306, United States

Director of the Intermediate Science Curriculum Study (ISCS), he is directing graduate students in science education and the ISCS programme. He has authored or edited 150 books, periodicals and articles in science education and has served as consultant for several Middle East, Australian, European and Latin American projects.

DR. HUBERT DYASI, Programme Director, Science Education Programme for Africa, PO Box 9169 Airport, Accra, Ghana

He has taught in science education in Sierra Leone and the United States and has written widely on science teaching and curriculum development. In 1978 he was Resident Foreign Curriculum Consultant and Visiting Associate Professor at the University of Illinois.

PROFESSOR PETER FENSHAM, Professor of Science Education, Monash University, Clayton, Victoria, Australia

With a number of research interests in science education and in higher education, he directed Man and the Physical World, a curriculum development project which provided rather new material for senior secondary students, intended to be an adequate scientific base for further study but also including much on the impact of science and technology on society. He was also Project Director of the Australian Science Teacher Education Project (ASTEP). For a number of years he has been a member of the Australian National Commission for Unesco and has represented his country at Unesco meetings for science and environmental education.

DR. RAFAEL FERREYRA, Regional Education Adviser, Unesco-PIA/PNAN, Magdalena 160, Santiago, Chile

Educated at Córdoba University, Argentina in engineering and at Harvard University in education, he was one of the authors of the Physics of Light course produced by the Unesco Pilot Project on the Teaching of Physics (Brazil, 1964) and has since then been active in its dissemination and evaluation in several countries. He is currently working in science teaching related activities as Unesco Regional Adviser to the Inter-Agency Project on Food and Nutrition Policies.

PROFESSOR KARL FREY, Managing Director, Institute for Science Education (IPN), University of Kiel, Olshausenstrasse 40-60, D-2300 Kiel, Federal Republic of Germany

professor of Education at Kiel University, he is former Head of the Curriculum Research Centre at the University of Fribourg in Switzerland, and has also been a teacher at primary and secondary levels. He has been involved in several science education projects and has authored numerous books and articles on science education and other matters.

DR. THOMAS GADSDEN, JR., Associate Professor, P.K. Yonge Laboratory School, University of Florida, Gainesville, Florida 32611, United States

Dr. Gadsden is currently teaching integrated science courses in high school while continuing development and revision of the *Correlated Science Program*. He is Director of the FUSE Center at Florida and Director of 'Unified Science Dissemination for Four Southeastern States', a project funded by the National Science Foundation. He is also involved in research concerning the process of curriculum development, dissemination and modification, and concerning learner differences and classroom management with respect to those differences.

MRS. SHEILA HAGGIS, Chief, Science Education Section, Division of Science, Technical and Vocational Education, Unesco, 7 place de Fontenoy, 75700 Paris, France

Originally from Sheffield, England, she has worked in secondary science teaching in England, Nigeria and Ghana, and was on the staff of the Department of Education, University of Ghana. She was secretary of the Ghana Association of Science Teachers from its foundation in 1955 until 1965. She has authored several text-books on integrated science and has been programme specialist for Unesco's programme in integrated science since its establishment in 1968.

DR. WYNNE HARLEN, Senior Research Fellow, Chelsea College, University of London, Pulton Place, London SW6 5PR, United Kingdom

A physics graduate from Oxford, she taught in schools and at a college of education before taking up research in primary science and the evaluation of curriculum development. From 1967 to 1973 she was engaged in the formative evaluation of the Science 5/13 project, becoming co-author of the guide to Science 5/13 *With Objectives in Mind* and author of *Science 5/13: A Formative Evaluation*. From 1973 to 1977 she was director of the Schools Council sponsored project 'Progress in Learning Science' which published books and other materials for in-service courses under the title *Match and Mismatch*.

DR. AVI HOFSTEIN, Department of Science Teaching, Weizmann Institute of Science, Rehovot, Israel

A member of the Department since 1967, he is currently involved in the development and evaluation of chemistry curricula at the secondary school level. He is also concerned with the use of case studies on specific chemical industries in Israel in the school curriculum.

ERNOS LAMBERT, Head, Science Department, Queen's Royal College, Maraval Road, Port-of-Spain, Trinidad & Tobago.

A teacher of chemistry, physics and integrated science up to senior secondary level, he has published an advanced chemistry text for the Caribbean. He is Convenor of the CXC Integrated Science Syllabus Panel and plays a leading part in the associated curriculum being developed by CROASE. From 1975 to 1978 he was President of the Association for Science Education of Trinidad & Tobago, and has assisted in courses and workshops in the Caribbean and elsewhere.

JOHN L. LEWIS, Senior Science Master, Malvern College, Malvern, Worcestershire, United Kingdom

Chairman of the ASE in 1977, Secretary of the International Commission on Physics Education until 1978, he is now Secretary of the Committee on the Teaching of Science of the International Council of Scientific Unions. He is a former organizer of the Nuffield Physics Project and is director of the ASE's Science in Society project.

PROFESSOR J. DAVID LOCKARD, Director, International Clearinghouse on Science and Mathematics Curricular Developments, University of Maryland, College Park, Maryland 20742, United States

Also Professor of Botany and Science Teaching at the University of Maryland, he has served as Director of the International Clearinghouse (one of the most comprehensive collections of such materials anywhere) since its inception in 1965. As well as teaching botany and science education courses, he conducts research on science curriculum analysis and evaluation, and on medicinal and poisonous plants. A former high school teacher and supervisor, his publications include work with a junior life science book, a senior high school biology text, three volumes on improvising inexpensive science teaching equipment, a series of international bibliographies on integrated science teaching, biology teaching and environmental education, the *New Unesco Source Book for Science Teaching* and the *Unesco Handbook for Science Teaching*. He served as President of the United States National Association for Research in Science Teaching and as the first President of ICASE. He now serves on the ICSU/CTS, IUBS Education Commission, NAS Unesco Science Program Committee and the United States National Commission for Unesco.

B.G. PITRE, Senior Physics Master, The Doon School, Dehra Dun, India

He has been Convenor of the Physics Curriculum Study Group of the All India Science Teachers Association and President of the Association, President of ICASE from 1975 to 1978, and Convenor of the regional seminar on environmental education for the Asian region, an Asian seminar held from December 1977 to January 1978.

PROFESSOR ISAIAS RAW, Professor of Biochemistry and Nutrition, School of Medical Education, City College, New York, NY 10013, United States (present address. Rua Itapicura 395, 05463 S. Paulo, Brazil)

Former professor of biochemistry of the University of São Paulo, he was founder and director of FUNBEC. He was Unesco expert to the Israeli Science Teaching Centre, visiting professor of the Harvard School of Public Health and the Massachusetts Institute of Technology, and is a member of ICSU-CTS.

MISS JUDITH REAY, Senior Lecturer, School of Education, University of the West Indies St. Augustine, Trinidad & Tobago

Originally from Fiji, she has taught physics and other sciences in schools in New Zealand, Fiji, Switzerland, Jamaica and England, and has conducted teacher education courses in Cameroun, Pakistan and the West Indies. At the University of the West Indies in Jamaica she directed the Science Education Project and the Science Education Centre and was one of the leaders of the MONA Project and WISC. She is currently with the in-service Diploma in Education programme in Trinidad & Tobago, and is a co-author of the *Unesco Handbook for Science Teaching*. In 1978 she was Vice-President of ASETT, and for some years since its foundation was Editor of the Association's publications.

DR. F. JAMES RUTHERFORD, Assistant Director for Science Education, National Science Foundation, Washington, DC 20550, United States

His first major contribution to integrated science teaching was as co-director and co-author of Harvard Project Physics, a major curriculum development project aimed at presenting physics in the context of the other natural sciences and of man's other cultural activities. Most recently he originated and directed Project City Science, a comprehensive programme for improving science teaching for the inner city in which integrated science was a major element. He has taught at a number of schools and universities in the United States.

DR. M. SABER SELIM, Director, Science Department, ALECSO, 109 Tahrir Street, Dokki Square, Cairo, Egypt

Educated at Cairo University and Stanford University, United States, he has taught in high school and at the College of Education in Cairo, and has served as Unesco Expert in Science Teaching in Iraq. He has supervised research in Technology of Science Education, and initiated the projects in biology and integrated science teaching in the Arab states.

DR. VICTOR SHOWALTER, Director, Center for Unified Science Education, Capital University, Columbus, Ohio 43209, United States

Executive Director of the Federation for Unified Science Education since 1966, he has taught unified science at various grade levels since 1959. He has also taught in several universities, produced several programmes for educational television, directed a number of research and development projects in science education, and authored *Man and the Environment*.

ROBERT L. SILBER, Executive Director, National Science Teachers Association, 1742 Connecticut Avenue, NW Washington, DC 20009, United States

A former teacher of chemistry at high school and college level, he served as staff member of the American Chemical Society in charge of membership, education, international programmes and other matters. In 1978 he was elected President of the International Council of Associations for Science Education (ICASE). He is the author of many articles and was a writer and member of the Steering Committee of CHEMStudy. He has organized several international conferences, the latest being a joint NSTA/CROASE conference in Barbados in 1979.

PROFESSOR CHARLES TAYLOR, Head of Physics Department, University College, PO Box 78, Cardiff CF1 1XL, United Kingdom

Originally from Hull (Yorkshire), Professor Taylor worked for the Admiralty and in industry before taking up university teaching, first in Manchester and later in Cardiff. He was chairman of the Physics Interface Project, is Professor of Experimental Physics at the Royal Institution of Great Britain, and Chairman of the International Council of Scientific Unions Committee on the Teaching of Science.

DR. JAN C. TERLOUW, Fractie D'66, Binnenhof 1a, Den Haag, Netherlands

Leader of his party in the Netherlands Parliament, his main fields of interest are environmental policy, industrial policy and energy policy. His background of research in nuclear energy includes work at the Massachusetts Institute of Technology and the Royal Institute of Technology in Stockholm.

JAN VAERNEWIJCK, Boswegel 8, B-9210, Heusden, Belgium

He teaches a wide variety of sciences at the State Technical Institute in Zelzate, and has taught in a number of upper secondary and technical schools. He is secretary of VeLeWe, the Flemish STA, and is Editor of the ICASE Newsletter.



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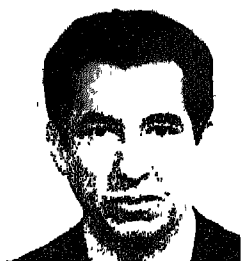
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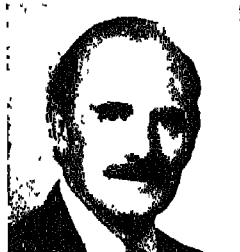
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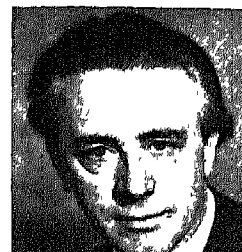
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Jan Vaernewijck

Appendix IV. Working group deliberations

Working Group 1 (Chapter 2)

- Chairman· Dr. Arthur Lucas, Chairman, School of Education, Flinders University of S.A., Bedford Park, South Australia 5042, Australia
- Rapporteurs· Dr. Eff Hofs, Head of Biology Department, Stichting Opleiden Leraren, Archimedeslaan 16, Postbus 14007, Netherlands
- Dr. Barbara Thomson, Associate Professor, Ohio State University, Arps Hall, Faculty of Science and Mathematics Education, Columbus, Ohio 43210, United States
- Papers Presented: Marshall, D.G., 25 Princes Gardens, Acton, London W3, United Kingdom
- An account of a new Inner London Education Authority science teaching project for 11-13 year old pupils 9p.*
- Through a series of relevant and enjoyable topics, the project aims to provide a sound base from which pupils are stimulated to pursue further scientific studies.
- Al Rashidi, M.S., Ministry of Education, Bahrain
- Man as the centre 1p.*
- Through science education as through other subjects of the curriculum, pupils must come to know themselves in addition to knowing science.
- Sood, J.K., Regional College of Education, Ajmer, India
- Extracts from Integrated Science for the Middle Stage of 10-12 Curriculum in India 3p.*
- The paper sets out a list of twenty-two 'abilities and values to be attained'.
- ten Voorde, H.H., Faculty of Science, University of Nijmegen, Nijmegen, Netherlands
- Why and how 4p.*
- Chemistry used as a vehicle for education.

Working Group 2 (Chapter 6)

- Chairman· Winston King, Lecturer, science education, School of Education, University of the West Indies Cave Hill, Barbados
- Rapporteur· Roger Garrett, Beech Hill High School, Dunstable Road, Luton, Bedfordshire, United Kingdom
- Subgroup Chairmen: Dr. J.H. Raat, Dept. Physics Teacher Education, Couperuslaan 1, Uithoorn, Netherlands

- Dr. Evhan Uzwyshyn, Science consultant, 53 Arrowwood Drive, N. Winnipeg, Manitoba, Canada RAV AR2
- Subgroup
Rapporteurs · E. Atua-Baadu, Assistant Director of Education, Ghana Education Service, PO Box M45, Accra, Ghana
- Dr. F. Arnold, Woeziksestraat 473, Wijkchen, Netherlands
- Douglas A. Black, Science Department, Sir Frederick Banting Junior Secondary School, 820 Banting Drive, Coquitlam, B.C., Canada V3J 4J4
- David C. Cox, FUSE Center at Portland, PO Box 22276, Milwaukie, Oregon 97222, United States
- Terry Grier, 1119 15th Street NW, Calgary, Alberta, Canada T2N 2B5
- J. Hoogeveen, SLO Centre for Curriculum Development, Von Weberlaan 1, Enschede, Netherlands
- Norman Massey, 197 Water Street, Cobourg, Ontario, Canada K9A 1R2
- Olusola A. Oyetola, Federal Government College, Ilorin, Nigeria
- Papers
Presented. Abu Sal, Mohammad, Curriculum Directorate, Science Division, PO Box 1930, Amman, Jordan
- The Experiment of integrated science in Jordan* 4p.
- Bandholm, Niels, Bakkegaarsvej 26, DK-8240 Risskov, Denmark
- Educational system of Denmark* 1p.
- Black, Douglas A. (Subgroup Rapporteur)
- Integrated science education in British Columbia* 2p.
- Both, Kees et al, Telgenkamp 19, Oldenzaal, Netherlands
- Integrated science education in the Netherlands* 2p.
- Cox, David, C. (Subgroup Rapporteur)
- The development of content and structure for integrated/unified science courses* 11p.
- Fenelova, Jitka and Pekarek, Ludek, Centre for Advancement of Physics Education, Institute of Physics, Czechoslovakia Academy of Science, Praha, Czechoslovakia
- Structure of Matter as integrated factor in science education* 16p.
- Garrett, Roger M. (Group Rapporteur)
- Integrated science in the United Kingdom* 1p.
- de Haese, Nicole, c/o Koninklyk Atheneum, Pottelberg 2A, 8500 Kortryk, Belgium
- The situation of integrated science in Flemish state schools* 1p.
- Hendriks, A.P., Ontginningsweg 85, Usselo, Netherlands
- Scheme of the educational system in Holland* 2p.
- King, Winston K. (Group Chairman)
- The status of integrated science in the Caribbean* 2p.
- de Kock, C., Hugo Verriestraat 37, 5044 PG Tilburg, Netherlands
- Integrated science in Holland* 1p.
- Massey, Norman (Subgroup Rapporteur)
- Across disciplines* 1p.
- Osiyale, Akin O., Department of Curriculum Studies, Faculty of Education, University of Lagos, Lagos, Nigeria
- The Nigerian Integrated Science Project example* 7p.
- Oyetola, Olusola A. (Subgroup Rapporteur)
- The status of integrated science in Nigeria* 3p.

Puri, O.P., Chairman, Division of Natural Sciences and Mathematics, Clark College, Atlanta, Georgia 30314, United States
Cooperative general science program 53p.

Uzwysyn, Evhan (Subgroup Chairman)
An integrated design of the junior high science program in Manitoba 5p.

Vegting, Paul, Rijks Universiteit Groningen, Afd. Vakdidaktiek Scheikunde, Chemische Laboratoria, Nijenborgh 16, Paddepoel, 9747 AG-Groningen, Netherlands
Basic ideas about science education 3p.

Veje, Carl Jorgen, Royal Danish School of Educational Studies, Department of Physics, Emdrupvej 115 B, DK-2400, Copenhagen NV, Denmark
Teaching of integrated science in Denmark 1p.

ten Voorde, H.H. (His paper for Working Group 1 was also considered by Group 2)

Winter, I.R., Senior Master, Ogilvie High School, 228 Main Road, New Town, Tasmania, Australia
Integrated science education in Tasmania 2p.

Xerri, Charles J., Education Office, Lascaris, Malta
Integrated science - the Maltese project 8p.

Working Group 3 (Chapter 12)

Chairman: Peter Richmond, Senior Lecturer, Department of Education, The University, Southampton SO9 5NH, United Kingdom

Rapporteur: Dr. Anthony Turner, Lecturer, Department of Science Education, Institute of Education, University of London, 20 Bedford Way, London WC1H 0AL, United Kingdom

Subgroup Chairman: Dr. J.B. van der Kooi, Lecturer, Laboratorium voor Medische Fysica, Der Rijksuniversiteit te Groningen, Bloemsingel 10, Groningen, Netherlands

Subgroup Rapporteurs: D. Holford, Lecturer, integrated science education, School of Education, University of Leicester, 21 University Road, Leicester, United Kingdom

Prof. Jay L. Lemke, City University of New York, Brooklyn College School of Education, Brooklyn, NY 11210, United States

Papers Presented: Arcà, M., Centro Acidi Nucleici, Istituto Fisiologie Generale; Vicentini-Missoni, M., Istituto di Fisica G. Marconi. Università Degli Studi, Piazzale delle Scienze, 5, Roma, Italy
Integrated science. meaning and aims for teachers, for children; with respect to disciplines, with respect to society 7p.

Lemke, J.L. (Subgroup Rapporteur)
Helping teachers widen social access to science 6p.

Mani, T.C., Department of Education, Ahmadu Bello University, Zaria, Nigeria
Education of teachers of integrated science at Ahmadu Bello University in Nigeria 19p.

Quiroz, C.A., INIDE-PRONAMEC, van der Velde 160, Urb. San Borja, Lima, Peru
National programme for the improvement of science education in Peru - a case study 33p.

Verkerk, G., Technical University, Eindhoven, Netherlands
Radioactivity and training of integrated science teachers

Working Group 4a (Chapter 8)

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Papers Presented: Alabi, Rufus S., Department of Biological Sciences, University of Ilorin. PMB 1515, Ilorin, Nigeria
Strategies and implementation of integrated science education at the secondary level

Pezaro, Peter E., Depts. of Isotope Research and Science Teaching, Weizmann Institute of Science, Rehovot, Israel
Upper secondary level: a way to integrate existing discipline-based courses by broadening their outlook. (An experiment in geochemistry) 13p.

Slimming, David, c/o British Council, 10 Spring Gardens, London SW1A 2BN, United Kingdom
Some factors influencing the implementation of secondary school integrated science in the Third World, with special reference to the Swaziland Integrated Science Project 1972-1976 11p.

Working Group 4c (Chapter 10)

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Paper Presented: Varela, H.F., Del Rio, S.J. and Furlán, A.J., Escuela Nacional de Estudios Profesionales, Iztacala, Universidad Nacional Autónoma de México, México
Enseñanza de ciencia integrada para la formación del medico experiencia de un cambio curricular en la ENEP-Iztacala-UNAM 36p.

Working Group 5 (Chapter 13)

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Papers Presented: Churchman, David, National Science Foundation, Washington, DC 20550, United States
Maximizing information from implementation of innovative courses 4p.
Kellington, Stuart, Notre Dame College of Education, Dowanhill, Glasgow G12 9JN, United Kingdom
Production and evaluation of the new materials for Scottish Integrated Science 12p.
Lutterodt, S.A., Department of Science Education, University of Cape Coast, Cape Coast, Ghana
The interaction of theoretical and contextual considerations in planning the evaluation of an integrated science course in Ghana 16p.

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Papers Presented: Capurro, Luis (Subgroup Chairman)
Some ideas about the future developments in integrated science education in relation to environmental education

Geller, Molly, School of Education and Community Services, Wm. Paterson College, Wayne, N.J. 07470, United States
The relationship between integrated science and environmental education: a teacher's view 2p.

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Papers Presented: Brathwaite, Workeley (Subgroup Chairman)
Relationship of integrated science to other school subjects in the curriculum

Maclay, R.W. de M- (Subgroup Rapporteur)
Integration of primary school experiences 9p.

Massey, Norman, 197 Water Street, Cobourgh, Ontario, Canada K9A1R2
Links with other school subjects 1p.

Quiroz, Cesar A. (Group Chairman) (His paper for Working Group 3 was also considered by Working Group 8)

Turner, Anthony D., Department of Science Education, Institute of Education, University of London, 20 Bedford Way, London WC1H 0AL, United Kingdom
A plea for co-operation between mathematics and science teachers in secondary schools 8p.

Working Group 9a (Chapter 18)

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Papers Presented: Arcà, M. (The paper for Working Group 3 was also considered by Working Group 10)

Ganguly, B. B., Department of Education in Science and Mathematics, NCERT, Sri Aurobindo Marg, New Delhi 110016, India
Science, society and trends in education - a few points to ponder 2p.

Manzelli, P., Istituto Chimica Fisica, Via G. Capponi No. 9, 50121 Firenze, Italy
A general outlook on science and society 5p.

Al Rashidi, M.S. (His paper for Working Group 1 was also considered by Working Group 10)

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Social issues in science education - an emerging trend 17p.

Sood, J.K., Regional College of Education, Ajmer, India
Science, society and science education a search for relevance in the developing countries 10 p.

ten Voorde, H.H., Faculty of Science, University of Nijmegen, Nijmegen, Netherlands
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